DISEASES OF THE EAR

POLITZER'S

TEXT-BOOK OF THE

DISEASES OF THE EAR

## FOR STUDENTS AND PRACTITIONERS

SIXTH EDITION

REVISED AND LARGELY REWRITTEN

BY

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WITH 302 ILLUSTRATIONS
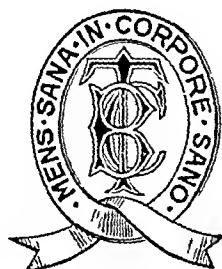
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PREFACE

Since the publication of the last edition of Politzer's *Textbook of the Diseases of the Ear*, otological literature has been greatly augmented by the addition of a large number of articles on the treatment and pathology of aural affections, and in particular on those conditions referable to the labyrinth or internal ear.

Having had the privilege of translating and editing the two previous editions, the time seemed opportune to the writer to bring out a new and revised edition of this standard work.

Every chapter has been carefully reviewed, such material eliminated which did not seem of sufficient importance, and new matter added which was regarded of greater interest and of more intrinsic value.

In doing so, however, the writer has endeavoured to retain as much as possible of the original text, and not to discard anything which would in any way jeopardize the value of this work. By omitting many of the less important items, it has been possible to reduce the size of this volume, thereby making it a more practical and handy reference book for the student and practitioner.

In bringing out this latest edition, it has been the writer's intention to present to his colleagues a clear and concise interpretation of the teachings of this illustrious scholar and clinician, Dr. Adam Politzer, which have extended over a long period of years, and which have been so fully embodied in his textbook on diseases of the ear.

MILTON J. BALLIN.

New York,
    April, 1926.

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THE ANATOMICAL DIVISION OF THE EAR.

THE sense-impressions, which we designate as sound-perceptions, are brought about by the specific excitation of the peripheral endings of the auditory nerve. Its delicate terminations lie upon membranous supports which are surrounded by an aqueous fluid, and which act as the transmitting medium for the waves of sound. These supports rest in a cavity which is partly formed by rigid walls.

Besides this essential sound-perceiving apparatus, the higher animals possess a sound-conducting apparatus which is endowed with the property of receiving the various waves of sound and conducting them to the labyrinth.

Accordingly, the organ of hearing is divided into two principal divisions—the sound-conducting and the sound-perceiving apparatus. We will adhere to this classification, as it is the only correct one from a physiological standpoint, and the more so because it can be combined with the older, practical, anatomical division of external, middle, and internal ear.

Each main division mentioned above is composed of many organs morphologically different. The organ of hearing is divided into—

1. The sound-conducting apparatus :
   - (a) The external ear (auricle and external auditory canal).
   - (b) The middle ear (the tympanic cavity, with the membrana tympani and ossicles, the Eustachian tube, and mastoid process).

2. The sound-perceiving apparatus, or internal ear:
   - (a) The labyrinth (vestibule, three semicircular canals. and the cochlea).
   - (b) The auditory nerve (central nuclei and roots, branches and peripheral endings in the labyrinth).

THE ANATOMY AND PHYSIOLOGY OF THE SOUND-CONDUCTING APPARATUS.

I. THE EXTERNAL EAR.

A. The Auricle (auricula).

The auricle is pyriform in shape. Its normal position is between two horizontal lines, the superior of which, if prolonged, would come into contact with the eyebrows, the inferior with the tip of the nose. It surrounds the external orifice of the ear, and is attached to the side of the head at an acute angle nearly midway between the forehead and the occiput. This angle is subject to manifold variations.

The concave surface of the auricle, directed forwards and outwards, presents a number of irregular elevations and depressions (Fig. 1). The external margin of the cartilaginous plate, the breadth of which varies, is rolled inwards, and forms the so-called *helix* (Fig. 1, *a*). It originates at the *crus helicis*, above the external orifice of the ear, in the deepest concavity of the auricle (*concha*); it extends from here upwards and backwards along the margin of the auricle, and ends above the posterior margin of the lobule in the *cauda helicis*. A second elevation, the *antihelix* (*b*), runs in a direction parallel to the posterior part of the helix, and is separated from it by a depression, the *scaphoid fossa ;* it begins above the crus helicis in two diverging roots directed anteriorly, and, running with a slight curve downwards, passes into a prominence directed forwards, the *antitragus* (*d*). Opposite to this, the inferior half of the cartilage forms a second, flap-like projection, the *tragus* (*c*); this is situated in front of the external auditory orifice, slightly overlapping it, and separated from the antitragus by a notch, the *incisura intertragica.* Below this notch, and forming the inferior extremity of the auricle, is the lobule (*lobulus auriculx*, e), which shows numerous individual variations, and is formed by the integument alone. The subcutaneous connective tissue is highly developed in this part, its meshes containing fat-cells, and only a small number of bloodvessels and nerves.

The integument of the auricle is more adherent to the perichondrium on the anterior than on the convex posterior surface; this is due to an increased development of the subcutaneous connective tissue, the skin thereby becoming more easily movable. The sebaceous glands in the concha excel all others in

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abundance and size. The cartilage of the auricle is about 2 mm. in thickness and is of the reticular variety. Its structure in man has been investigated by His, Rohrer, and Münch (*Morpholog. Arbeiten*, 1897).

The muscles of the auricle are divided into two groups. The first group controls the movements of the whole auricle, and are the following:

1. The *musculus auricularis superior*, a thin, fan-shaped, radiating muscle, arises from the epicranial aponeurosis, and, with its fibres converging in a downward direction, is inserted into the convex surface of the auricle; it draws the auricle upwards.

2. The *musculus auricularis anterior* arises in front of the auricle above the zygomatic process, and also from the epicranial aponeurosis, and is inserted at the crista helicis; it draws the auricle slightly forwards and upwards.

3. The *musculus auricularis posterior*, which consists of several fasciculi, arises behind the auricle from the mastoid process, and is inserted into the convex surface of the concha; its action is to draw the auricle slightly backwards.

The muscles of the second group have their origin and insertion on the auricle itself. They effect a change in the form of the auricle, but only to a slight degree. The *tragicus, antitragicus, helicis major* and *minor* lie on the concave surface, the *transversus* and *obliquus auriculæ* on the convex surface.

Imhofer (*Arch. f. Krimin. Anthropol.*, vol. xxvi.) is of opinion that certain peculiarities of formation of the auricle are often hereditary, and considers them as

FIG. 1.—AURICLE.

a, Helix; *b*, Antihelix; *c*, Tragus; *d*, Antitragus; *e*, Lobule; *f*, Concha; *g*, Orifice of the external meatus.

an important aid in the establishment of descendants—for example, in cases in which the parentage of a child is in doubt. The criminal school of Italy, of which Lombroso was at the head, considered anomalies in the formation of the auricle as degenerative changes. Gradenigo (*A. f. O.*, vol. xxii.) found these anomalies most frequently among the insane and criminals. Bertillon, Blau, and others incline towards this latter theory (cp. G. Schwalbe, '*Das äussere Ohr*,' in *Bardeleben's Handbuch der Anatomie des Menschen*, Jena, Fischer, 1898).

B. The External Auditory Canal (meatus auditorius externus).

The external auditory canal is divided into the *cartilagino-membranous* and *bony* parts.

(a) The Cartilagino-membranous Meatus.

The cartilagino-membranous meatus is a tubular continuation of the auricle directed inwards (medially). This tube consists of a cartilaginous channel, which is formed above and somewhat posteriorly into a canal by its union with the lining membrane of the external auditory meatus.

The circumference of the cartilaginous channel (Fig. 2) appears greatest at its outer, lateral extremity, while medially the width of the cartilage decreases in such a manner that the inner extremity (*b*) appears as a narrow, rounded point.

The proportion of the cartilaginous to the membranous portion is clearly shown by sections (Figs. 3, 4, 5) made perpendicularly to the axis of the cartilagino-membranous meatus, at its outer, middle, and inner portions. These show that the membranous portion (*b*, Figs. 3, 4, 5) increases in breadth towards the interior, while the cartilaginous portion correspondingly decreases. The length of the inferior cartilaginous wall varies from 10-11 mm. from the entrance of the meatus to the point of the cartilage.

FIG. 2.—AURICLE AND CARTILAGINOUS MEATUS.

a, Cartilaginous meatus; *b*, Interior pointed extremity of the cartilaginous meatus; *c*, *c*, Fissures of Santorini. (Left ear.)

The cartilaginous channel of the external auditory canal, which varies in thickness in different places from 1–3 mm., is traversed by several fissures (Fig. 2, *c*, *c*), *incisuræ cartilaginis meatus auditori externi* (incisuræ Santorini); these run in a direction nearly at right angles to the long axis of the meatus. As a rule, two large fissures, filled with fibrous tissue, are found, through which the anastomosis of the vessels between the
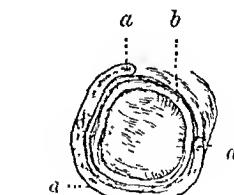
FIG. 3.—SECTION OF THE CARTILAGINOUS MEATUS CLOSE BEHIND THE ORIFICE OF THE EXTERNAL MEATUS.

a, *a*, *a*. Cartilaginous channel; *b*, Fibrous layer.
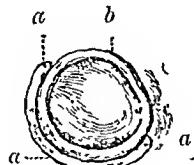
FIG. 4. — SECTION THROUGH THE MIDDLE OF THE CARTILAGINOUS MEATUS.

a, *a*, *a*, Cartilaginous channel; *b*, Fibrous layer.
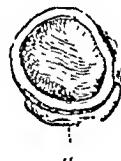
FIG. 5.—SECTION IN THE NEIGHBOURHOOD OF THE INNER EXTREMITY OF THE CARTILAGINOUS MEATUS.

a, Cartilage; *b*, Fibrous layer.

anterior and posterior surfaces of the ear (Pareidt) takes place. They permit the straightening of the meatus during examination of the membrana tympani and during operative procedures, and allow a certain amount of flexibility of the cartilage (Ostmann).

Abscesses of the parotid gland not infrequently break through these fissures into the external auditory canal.

The medial end of the cartilaginous meatus is attached by an intervening, flexible connective-tissue substance to the rim of the osseous meatus, which is covered by tough, elastic fibrous tissue. This attachment takes place only at the rough edge of the osseous meatus, which corresponds to the pars tympanica (Fig. 8); superiorly and posteriorly the fibrous part of the cartilaginous meatus passes directly into the lining membrane of the superior wall of the osseous meatus.

(b) The Osseous Meatus.

1. **Development.**—The anatomical relations of the osseous meatus are essentially different in the new-born and in the adult. In the infant, instead of the osseous meatus, one finds an osseous ring (*annulus tympanicus*), to the exterior margin of which a membranous canal is attached, forming one half of the entire auditory canal. As the infant advances in age, the cartilaginous meatus becomes smaller, while the *pars tympanica ossis temporalis* enlarges.

According to Arnold, the temporal bone consists of three parts, which develop independently. These are the squamous, tympanic, and petrous portions.

The osseous meatus is developed principally from two different bony parts, namely, the squamous and tympanic portions of the temporal bone.*

The tympanic portion of the temporal bone in the new-born consists of a ring (*annulus tympanicus*) (Fig. 6), which is incomplete superiorly and anteriorly, and is provided with a groove for the reception of the tympanic membrane; this ring is attached by its free extremities to the inferior part of the external surface of the squamous portion. The space between the two places of attachment of the tympanic to the squamous portion we shall see later is the anterior, superior, grooveless segment of the tympanic ring (*incisura tympanica*, Rivini).

As the cranial bones develop in the first years of life, the following changes take place in the squamous and tympanic portions. The superior part of the squamous portion (Fig. 7, *a*) advances externally on the lateral part of the cranium, while its lower portion (*b*), which lies beneath the zygomatic process, takes a more horizontal position; the ultimate result of this is that in the fully developed temporal bone, the superior part of the squamous portion (Fig. 9, *a*) is bent almost at a right angle to its inferior, horizontal part (*b*). This horizontal portion forms the superior wall of the osseous meatus, and also a portion of the posterior wall in conjunction with the mastoid process.

These changes in the squamous portion are brought about by the growth of the tympanic portion which forms the essential part in the construction of the osseous meatus. Through the deposit of bony masses on the external surface of the tympanic ring, which at first begins at two projecting points, a groove is formed (Fig. 8, *b*), the lateral walls of which reach so far towards the Rivinian segment that they more or less take part in the formation of the superior wall of the external auditory canal (Zuckerkandl).

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* Cp. Politzer, *Geschichte der Ohrenheilkunde*, vol. i.; Du Verney, p. 196.

In the fully developed temporal bone, the groove-like tympanic portion (Fig. 8) appears as if pushed from below into the shallow sulcus (*a*), formed by the horizontal part of the squamous bone and the mastoid process. The

FIG. 6.—OUTER SURFACE OF THE TYMPANIC RING.

a, Anterior tympanic tubercle; *p*, Posterior tympanic tubercle.

FIG. 7.—TEMPORAL BONE IN THE NEW-BORN INFANT.

a, Superior part of the squamous bone; *b*, Its inferior part below the line of the zygomatic process; *c*, Annulus tympanicus; *d*, *d*, The fissure between squamous portion and mastoid process, reaching to the foramen stylo-mastoideum; *e*, Foramen stylo-mastoideum; *f*, Fenestra ovalis; *g*, Fenestra rotunda. (Left ear.)

FIG. 6A.—INNER SURFACE OF THE TYMPANIC RING.

st, Tympanic sulcus; *p*, Posterior tympanic tubercle; *s*. Spina with the below it. (Left ear.)

entire inferior and anterior walls of the meatus are therefore formed by the tympanic portion, while the tympanic, mastoid and squamous portions participate in the construction of the posterior wall, the latter in a great measure through its lamina mastoidea, which forms the anterior surface of the mastoid process.

FIG. 8.—OSSEOUS MEATUS IN THE ADULT.

a, Horizontal part of the squamous bone (superior wall of the meatus); *b*, Tympanic portion; *c*, Lumen of the meatus; *d*, Mastoid process. (Left ear.)

The encroachment of the tympanic portion on the squamous and mastoid parts soon causes the boundary-line between them to be entirely effaced. The margins of the tympanic portion soon lift themselves prominently from the pars mastoidea, and one finds, in the fissures thus formed, connective-tissue prolongations rich in blood-vessels. These prolongations penetrate deeply into the mastoid, and facilitate the discharge of any suppurative process existing there into the external auditory canal.*

2. The Construction of the Osseous Meatus.

—The osseous portion of the external auditory canal is connected with the

* Cp. A. Politzer, *Die anatomische und histologische Zergliederung des menschlichen Gehörorgans im gesunden und kranken Zustande.* Stuttgart, 1899, p. 34.

cartilaginous portion at its external margin, while at its internal widened extremity the tympanic membrane is stretched in the shallow groove of the sulcus tympanicus. We differentiate a *superior, inferior, anterior,* and *posterior* wall.

Superior Wall.—This strongly developed wall (Fig. 9, *b*) appears bent almost at a right angle to the squamous portion (*a*) of the temporal bone, and is formed by two osseous plates, between which one finds partly diploë and partly pneumatic cells. The superior plate is turned towards the cranial cavity, the inferior towards the lumen of the meatus.

The upper, shorter lamella meets the tegmen tympani at the petrosquamous suture which crosses over the external auditory canal, and also joins posteriorly with the roof of the mastoid antrum; the inferior lamella extends to the tympanic cavity, where it ends in a concave, sharp, grooveless edge, directed inwards and downwards (*margo tympanicus* of the temporal bone), into which the upper periphery of the *pars flaccida* is inserted.
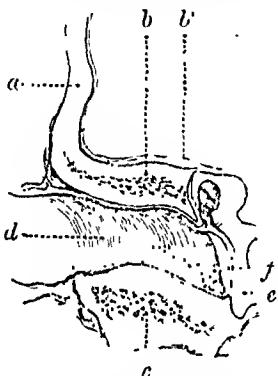
FIG. 9.—FRONTAL SECTION THROUGH OSSEOUS MEATUS AND TYMPANIC CAVITY.

a, Squamous portion; *b*, Superior wall of the osseous meatus; *b'*, Dura mater; *c*, Inferior wall of the osseous meatus; *d*, Meatus; *e*, Membrana tympani with the malleus; *f*, Tympanic cavity. (Left ear.)

FIG. 10.—HORIZONTAL SECTION OF THE EXTERNAL MEATUS AND TYMPANIC CAVITY.

a, Anterior wall of the meatus; *b*, Posterior wall; *c*, Cells of the mastoid process; *d*, Meatus; *e*, Membrana tympani; *f*, Tympanic cavity; *g*, Sinus transversus. (Right ear.)

This wall lies in the region of the middle fossa of the skull, so that carious destruction of this wall may encroach upon the dura mater and bring about a fatal meningitis.

Inferior Wall.—The inferior wall (Fig. 9, *c*) of the osseous meatus appears thick and compact on section. The surface directed towards the meatus is convex in its long axis, the greatest convexity being usually found at the border of its inner third. This convexity passes into a considerable concavity near the membrana tympani (Fig. 9) (*sinus meatus externi*, H. Meyer), and forms, in conjunction with the membrane placed obliquely at an acute angle to the meatus, a space in which small foreign bodies frequently become lodged.

A comparison of the lengths of the superior (14 mm.) and inferior walls (16 mm.) shows that the superior (*b*) extends further externally, and that the inferior (*c*) reaches 6-8 mm. further medially. For this reason, as well as through the unequal lengths of the anterior and posterior walls, the membrane is placed obliquely to the axis of the auditory canal; this fact must be considered in the examination of the membrane, as well as in operations.

Anterior Wall.—This wall (Fig. 10, *a*) (17-18 mm.) is comparatively thinner than the other walls, and is more or less strongly bulged towards the

lumen of the meatus, especially at the boundary of its inner third; it extends 7–8 mm. further medially than the posterior wall.

The defects in the anterior wall observed during the earlier years of life (which were already known to Riolan, Valsalva, and Cassebohm) arise, according to Zuckerkandl, from the rapid growth of the anterior and posterior tubercles of the tympanic ring, which form one or more spaces by a bridge-like union. These generally close in the third year of life, but are frequently met with in the adult temporal bone as persistent spaces closed by a membrane (Arnold v. Tröltsch).

The internal part of the cartilaginous, as well as the anterior wall of the osseous meatus, lie immediately behind the maxillary joint; therefore movements of the inferior maxilla cause a change in the lumen of the cartilaginous meatus. Violence applied to this bone may produce fracture of the anterior osseous wall.

Posterior Wall.—This wall (15–16 mm.) is mainly formed internally by the tympanic portion of the temporal bone, externally, however, by the pars mastoidea. It extends further externally than the inferior and anterior walls.

During the growth of the temporal bone, the cells of the mastoid process advance externally in conjunction with the greater mass of cell spaces lying behind the posterior wall. The mastoid cells are therefore covered anteriorly by the posterior wall of the osseous meatus, and from this fact one can see the important relation of this wall to the mastoid. Frequently caries of the latter extends to the posterior wall, and the sequestra are discharged into the external auditory canal.

(c) The Lining Membrane of the External Auditory Canal.

The lining of the external auditory canal, a continuation of the external integument, is much thicker in the cartilaginous than in the osseous portion; in the latter the cutis gradually becomes more delicate and thinner as it approaches the sulcus of the membrana tympani. On the superior wall of the osseous meatus, however, a somewhat stronger band of cutis extends to the membrane. The dermic layer of the cartilaginous portion, 1–2 mm. in thickness, has an abundant growth of hair, into the sacs of which sacculated sebaceous glands discharge. We also find ceruminous glands (glandulæ ceruminosæ) in the deeper layers of the cutis more or less compact. They are of a yellowish-brown colour, and belong to the tubular glands. The ducts are coiled just as those of the sudoriparous glands (Kölliker); they are 0·2–1·5 mm. in diameter, and discharge either directly into the meatus by means of a straight canal 0·01 mm. wide, or into the upper portion of the hair sacs (Henle). The orifices of the ducts can be seen with the naked eye as closely arranged dots in the external auditory canal (Fig. 11,
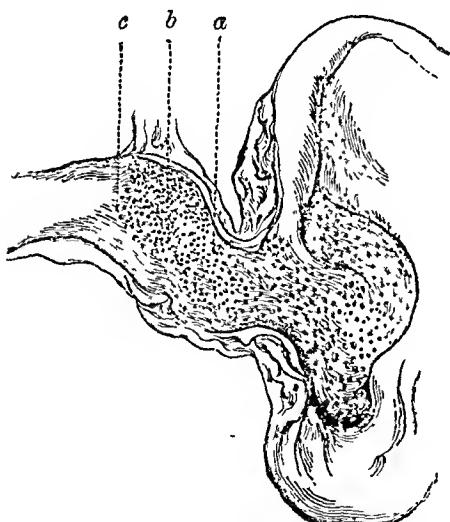
Fig. 11.—Posterior Wall of the Cartilaginous and Osseous Meatus.

a, Orifices of glands in the cartilaginous portion; *b*, Boundary between cartilaginous and osseous meatus; *c*, Apex of the triangular glandular portion of the meatus which enters the osseous meatus.

a, *b*, *c*). The ceruminous glands are lined with a single layer of pavement epithelium resting on a membrana propria and a layer of smooth muscle fibres

According to Soemmerring and v. Tröltsch, the glandular layer extends from the posterior superior wall of the cartilaginous portion into the osseous meatus in the form of a triangle several millimetres long (Fig. 11, place between *b* and *c*), the apex of which (*c*) is directed towards the membrana tympani. The glandular elements are wanting in the other parts of the osseous meatus; the more delicate cutis, firmly united with the periosteum, forms compact, spirally arranged folds (Kaufmann), and contains only a few papillæ (*Medic. Jahrbücher*, 1866), which often become hypertrophied in inflammatory affections, and frequently form the basis of large, compact polypi.

(*d*) The Vessels and Nerves of the Auricle and External Auditory Canal.

Arteries.—The arteries of the auricle and of the external auditory canal arise from the temporal and internal maxillary. The anterior surface of the auricle, as well as the external portion of the meatus, are supplied by the anterior auricular branches of the superficial temporal artery. A branch of the posterior auricular artery, arising from the external carotid, supplies the posterior surface of the auricle. The blood-supply to the deeper portions of the external auditory canal is provided by the deep auricular artery, a branch of the internal maxillary. The smaller branches of these arteries are distributed as follows: Some pierce the membrane which roofs over the cartilaginous meatus, some the fissures of Santorini, and others the fibrous connective tissue which unites the cartilaginous with the osseous meatus. They then ramify in the lining membrane of the auditory canal, and form a fine capillary network on the perichondrium in the region of the sweat glands, the hair follicles, and the sebaceous glands. A vascular bundle of considerable size extends along the superior wall of the meatus to the superior periphery of the membrana tympani, and passes on to the membrane with a band of connective tissue, which will be described later; it then extends along the posterior margin of the manubrium to its inferior extremity.

Veins.—The veins of the auricle and of the external auditory canal present numerous variations in regard to their union with the larger venous trunks on the lateral portions of the head. The anterior, posterior and deep auricular veins generally empty into the external jugular and mastoid veins; a portion of the veins of the external ear empty into the temporal and internal maxillary veins.

Lymphatics.—Regarding the lymphatics of the external auditory canal, the author has already pointed out that they are probably in close connection with the lymphatics on the mastoid process and on the parotid gland, for we often find, in inflammatory affections of the meatus, that the lymphatics in the neighbourhood of the ear become enlarged. Recent investigations have shown that the lymphatics of the anterior and superior walls of the meatus, the tragus, and the surrounding parts, empty into the pre-auricular glands (on the parotid), that those of the lobule, the helix, and the inferior wall of the meatus, empty into the infra-auricular glands (in the angle of the jaw), that those of the anti-helix and the concha empty into the mastoid glands (on the apex of the mastoid process), and that those of the posterior wall of the meatus, together with those of the Eustachian tube, empty into the deep cervical and retropharyngeal glands (Stahr, Poirier-Cunéo, Most).

Nerves.—The nerves of the auricle and external meatus arise from the facial, which sends the posterior auricular branch to the posterior surface of the auricle; from the trifacial, the third branch of which, in conjunction with some twigs of the auriculo-temporal, supplies the skin of the auricle and external meatus. The cervical plexus also supplies the external ear through its great auricular branch; the pneumogastric assists in the supply of the external meatus through its auricular branch, which was discovered by Arnold, and which arises from the jugular ganglion; it per-

forates the posterior wall of the meatus as a considerable branch, and supplies its lining membrane. A larger branch extends from the superior wall of the meatus to the membrane.

(e) The Size, Length, and Direction of the External Auditory Canal.

Size.—The size of the external auditory canal in the adult is subject to many individual variations. The cartilaginous portion is often so spacious that the little finger can easily be inserted as far as the osseous portion, while in others it is narrowed to the diameter of a goose-quill. The lumen of the cartilaginous canal, which is 5–7 mm. at the orifice of the ear, widens to 9–11 mm. in its inner part. It presents a moderate narrowing at its place of union with the osseous meatus (7–9 mm.), and again suddenly enlarges at the beginning of the bony canal. The cartilaginous canal is narrower in children than in adults, which therefore makes examinations and operations more difficult. On the other hand, in old persons a slit-like closure of the external orifice of the ear often takes place in consequence of atrophy and shrinking of the cartilage.

The width of the osseous meatus also presents many individual variations. Its lumen gradually becomes smaller in passing inwards (Fig. 9), being most con-

Fig. 12.—Section of the External Meatus.

a, Lumen of the meatus; b, Anterior wall; c, Mastoid cells.

stricted at the margin of the inner third (*isthmus*), and again increasing at the membrane. The lumen of this canal is somewhat round externally, and elliptical in its deeper portions beyond the isthmus (Fig. 12); the larger diameter of the ellipse is not perpendicular, but slightly inclined forwards. From the foregoing it follows that the isthmus is that part of the osseous meatus where the anterior and inferior walls form the greatest convexity.

This is the place where foreign bodies become wedged, and where, if they penetrate more deeply, the greatest obstacle is offered to their extraction; it is, therefore, important to know that the distance from the anterior portion of the isthmus to the anterior periphery of the membrane is 7–8 mm., while the distance from the posterior portion of the isthmus to the posterior periphery of the membrane is only 1–2 mm. This being the case, in attempts at extraction, the instrument must be passed along the superior and posterior walls with great caution to avoid injuring the membrana tympani. At the isthmus the transverse diameter of the osseous meatus averages 5 mm., the vertical diameter 9 mm.; the diameter of its internal extremity is 10 mm. in the vertical and 4·2 mm. in the transverse. According to Bezold, the long diameter at the commencement of the osseous meatus is 8·67 mm., the short diameter 6·07 mm.; internally, and at a point corresponding to the external pole of the membrane, these diameters are 8·13 mm. and 4·6 mm. respec-

tively. According to Ostmann (*Mitteil. f. O.*, 1893), a more circular auditory canal is generally found in diacephalic skulls, and a more oval one in brachycephalic skulls.

Length.—The lengths of the different walls, from the external orifice to the insertion of the membrane, are unequal. V. Tröltsch assumes, as the external boundary of the meatus, a sagittal plane passing through the posterior margin of the orifice; according to his measurements, the length of the superior wall is 21 mm., the inferior 26 mm., the anterior 27 mm., and the posterior 22 mm. On an average the length of the entire meatus is 24 mm., of which more than one-third is taken up by the cartilaginous portion.

Direction.—The external meatus presents several curves from the external orifice to the membrane, which must be borne in
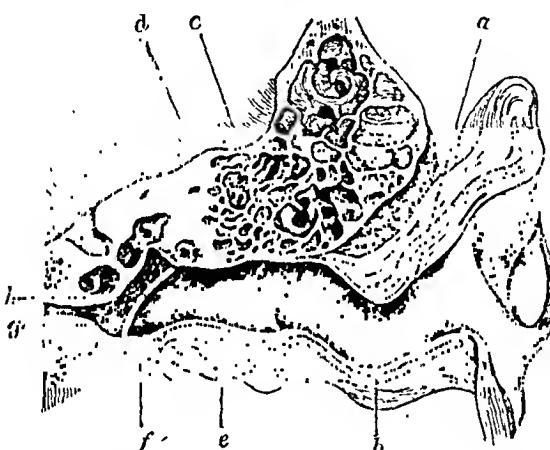
FIG. 13.—HORIZONTAL SECTION OF THE EXTERNAL MEATUS.

a, Concha; *b*, Tragus; *c*, Place of attachment of the cartilaginous portion; *d*, Mastoid process; *e*, Anterior wall of the meatus; *f*, Sin. meat. audit. extern.; *g*, Membrana tympani; *h*, Tympanic cavity. (Left ear.)

mind in examination of the latter, as well as in operations in the canal. Although the entire meatus appears spirally twisted about its axis, it may be assumed that the cartilaginous portion in passing inwards turns backwards and upwards, and the osseous portion forwards and downwards. The long axes of the two portions of the canal therefore form an open angle forwards and downwards, and as the meatus slopes inwards and outwards from the place of union, the inferior part of the external auditory orifice and of the membrana tympani must lie lower than the other parts of the canal.

II. THE MIDDLE EAR.

THE middle ear, the most important part of the auditory apparatus from a pathological standpoint, is divided into—

1. **The Tympanic Cavity.**
2. **The Eustachian Tube.**
3. **The Mastoid Process.**

1. The Tympanic Cavity.

The tympanic cavity (Henle) is an irregular, three-sided prismatic space (Fig. 9, *f*) compressed from without inwards; the diameters from above downwards, and from before backwards, are greater than from without inwards. It is divided into three parts.

1. *The Superior Tympanic Cavity* [cavum epitympanicum (Schwalbe), attic (Leidy), cupola (Hartmann)], which contains the head of the malleus and body of the incus, is bounded above by the tegmen tympani, and below by the horizontal portion of the facial canal and the tendon of the tensor tympani muscle.

2. *The Middle Tympanic Cavity* (atrium, mesotympanicum, Kümmel), which takes in the tympanic membrane and the promontory wall.

3. *The Inferior Tympanic Cavity* (cavum hypotympanicum, Kretschmann; cellar) reaches from the inferior border of the sulcus tympanicus to the floor of the tympanum.*

Although the walls forming this cavity are not sharply defined, it is, nevertheless, necessary for a clear understanding of its anatomical relations to describe the tympanum as being made up of different regions or walls. We will begin with a description of its external wall, and as the membrana tympani forms its greater part, we will commence with its anatomical relations.

The common names of the tympanic walls—*external, internal, superior,* and *inferior*—do not correspond to their actual positions, as the direction of the cavity from above downwards is not perpendicular, but oblique from above downwards and inwards (medially). If, in spite of the above, we still adhere to the old names, we must never lose sight of the fact that in the normal position of the head the external wall becomes an external inferior by its inclination; the internal wall, which roofs over the external, an internal superior; the inferior wall, an inferior internal; and the superior wall, a superior external.† These relations are of great practical importance.

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* Cp. A. Politzer, *Zehn Wandtafeln zur Anatomie des Gehörorgans.* Wien, 1873. Braumüller, Plate iii.
† Cp. Schöneman, *Topographie der Trommelhöhle*, 1905.

(a) The Membrana Tympani.

The membrana tympani is situated at the inner extremity of the osseous meatus, and appears as an irregular, oval, concave membrane, placed obliquely to the longitudinal axis of the canal in a groove-like sulcus (*sulcus tympanicus*). This sulcus belongs to the tympanic ring, already mentioned (Fig. 6), and is present in the adult temporal bone as the original position of the tympanic ring. Anteriorly and superiorly, however, at the incisura tympanica (Rivini) (Fig. 14, *b*) the sulcus is entirely lacking, and the *pars flaccida*, located here, is partly united with the grooveless margo tympanicus and partly with the ligamentum mallei laterale.

Form.—Its shape may be elliptic, irregularly oval, and heart-shaped. The membrane is bulged out at two places in its periphery — namely, posteriorly and superiorly — into a large segment of a circle (Fig. 14, *c*); and anteriorly at the incisura tympanica (Figs. 14, *b*; 15, *c*; and 16, *s*) above the short process of the malleus. This latter segment is demarcated from the remaining tympanic sulcus by two more or less sharply defined angular projections (Figs. 14 and 15), the distance from each other at the base being $2\frac{1}{2}$–3 mm.; the height of this rounded segment is about 2 mm.

Size.—The size of the membrane presents more or less variations in

FIG. 14.—SULCUS OF THE MEMBRANA TYMPANI AT THE INNER EXTREMITY OF THE MEATUS.

a, Sulcus; *b*, Anterior superior grooveless bulging of the periphery of the membrana tympani (margo tympanicus) or Rivinian segment; *c*, Osseous wall of the tympanic cavity behind the membrana tympani; *d*, External wall of the tympanic cavity extending into the Eustachian tube. (Right ear.)

different individuals. According to numerous measurements taken by the author, the greatest longitudinal diameter from the point of the spina tympanica posterior to the lowest point of the inferior margin of the membrane is $9\frac{1}{2}$–10 mm.; the greatest transverse diameter, from the anterior to the posterior periphery, is $8\frac{1}{2}$–9 mm. Bezold's measurements on corrosion specimens give the average of the two diameters as 9·2 and 8·5 mm. According to Schwalbe, the square measurement of the membrane is $69\frac{1}{2}$ mm². The thickness of the membrane between the handle and the tendinous ring is 0·10 mm. (Henle).

Inclination.—The inclination of the membrane in the adult depends on the inclination of the somewhat spirally curved sulcus tympanicus to the axis of the meatus. Its inclination will be greater the further the anterior and inferior walls of the meatus

reach internally beyond the posterior and superior walls (Figs. 9 and 10). One differentiates, therefore, a vertical and a horizontal inclination. The former, according to Schwalbe, is designated *inclination*, the latter *declination*. Bezold's measurements on corrosion specimens gave the average angle as 27°–35°. V. Tröltsch estimated the angle which the plane of the membrane forms with the superior wall at an average of 140°. According to J. Pollak, there is no perceptible difference in the inclination of the membrane in the new-born and in the adult. It is, however, to be noted that the separate portions of the membrane exhibit a different inclination to the horizontal. The anterior inferior quadrant forms an angle of 75°–85° with the axis of the meatus when the head is in a vertical position; the posterior superior quadrant, an angle of 150°.
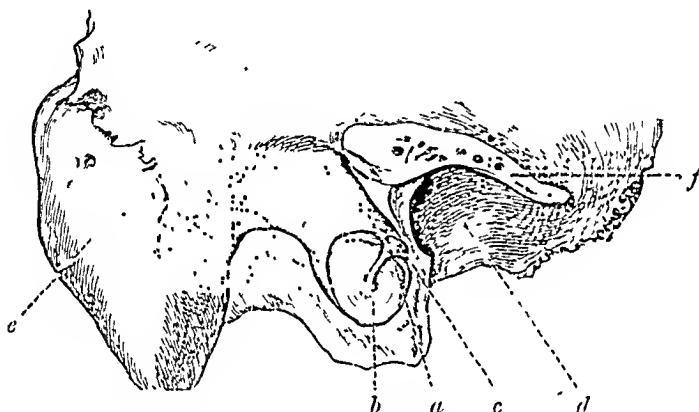
FIG. 15.—EXTERNAL SURFACE OF THE MEMBRANA TYMPANI (NATURAL SIZE).

a, Short process of the malleus; *b*, Inferior extremity of the handle of the malleus (umbo); *c*, Membrana flaccida Shrapnell; *d*, Fossa mandibularis; *e*, Mastoid process; *f*, Section of the zygomatic process. (Right ear.)

Curvature.—The obliquely-placed membrane is curved in such a manner that its concavity is directed outwards, its convexity inwards (Fig. 9, *c*). The greatest point of curvature, the umbo, corresponds to the inferior extremity of the manubrium, which is enclosed in the layers of the membrane. Through the inward traction of the handle, the membrane appears funnel-shaped. The membrane appears, as a whole, concave externally; still, there is a deviation from this regular curvature, in so far as the anterior and inferior portion between the umbo and the periphery is decidedly convex externally (Fig. 9). The portion situated posterior to the handle appears flatter, and shows a less regular curvature than the anterior and inferior parts.

The hammer is a structure in close relation with the membrane (Figs. 15 and 16); its shaft-like handle is intimately united with

the layers of the membrane, and is strongly inclined inwards; it extends in an oblique direction from in front and above, downwards and backwards, and ends at the umbo in a spade-like extremity (Fig. 15, b).

The handle of the malleus, which divides the membrana tympani into two unequal parts—an anterior smaller (Fig. 16, v), and a posterior larger (h)—extends forwards and upwards, and ends at the processus brevis (Fig. 15, a).

The short process is recognized as a marked, knob-shaped projection at the anterior superior pole of the membrane. From here two more or less prominent folds run anteriorly and posteriorly; when the membrane is abnormally retracted, the posterior one has the appearance of a grey tendinous band, the diagnostic significance of which will be pointed out in a later chapter. A third, less prominent fold is seen to extend to the incisura tympanica, and is a part of Shrapnell's membrane.

One finds, near and above these folds, two short, straight striæ at the anterior superior pole of the membrane; these take their origin from the corners of the Rivinian segment, and converge towards the point of the short process (Fig. 16, s, s'). These striæ, which were first described by Prussak (attachment striæ of the membrana tympani, Helmholtz), and which during life are frequently visible as white lines, appear somewhat sunken in dried specimens. This slightly depressed portion of the membrane (Fig. 16, ms), which is bounded by these striæ and the grooveless Rivinian segment, is commonly called the pars flaccida (Shrapnell's membrane). This is much thinner and less tense than the other parts of the membrane (pars tensa), and forms the external wall of a small space (Prussak's space) which communicates with the tympanic cavity. The height of the pars flaccida is 1½ mm.. the width at the base 2 mm.

FIG. 16.—OUTER SURFACE OF THE LEFT TYMPANIC MEMBRANE OF AN ADULT, ENLARGED 3½ TIMES.

v, Segment of the tympanic membrane lying in front of the handle of the malleus; h, Posterior segment of the tympanic membrane; s, s', Prussak's striæ, passing from the short process of the malleus to the spina tympanica major et minor; ms, Shrapnell's membrane.

The first structures which attract our attention on the inner surface of the inwardly retracted membrane are the head of the malleus and the body of the incus intimately connected with it (Fig. 17, a, g). The neck of the malleus (Fig. 17, b) is found

below the head, from which the handle proceeds downwards and backwards (Figs. 16 and 17, *d*). In spite of its close connection with the membrane, it stands away so far that it appears as if it were simply lying upon its inner surface. If the incus is removed, a duplicature, described by Cornelius,[*] and later by v. Tröltsch, is found on the posterior superior segment of the membrane; it arises from a slightly rounded ridge of bone within the sulcus, and from the posterior superior periphery of the annulus tympanicus (*limbus membranæ tympani*) runs anteriorly and superiorly, and is attached to the posterior surface of the manubrium. This fold, standing away from the
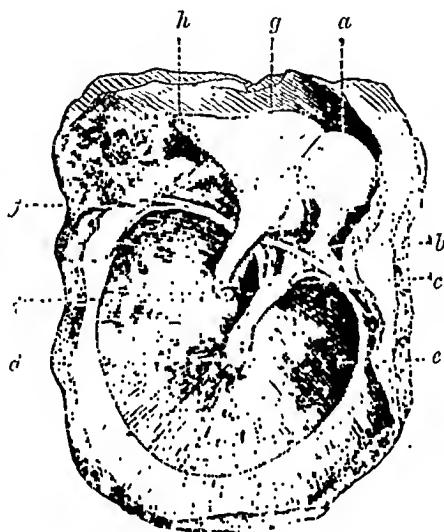
FIG. 17.—INTERNAL SURFACE OF THE LEFT MEMBRANA TYMPANI (ENLARGED).

a, Head of the malleus; *b*, Neck of the malleus; *c*, Tendon of the tensor tympani and anterior fold of the membrana tympani; *d*, Inferior extremity of the handle of the malleus; *e*, Anterior portion of the membrana tympani; *f*, Posterior fold of the membrana tympani and chorda tympani; *g*, Incus; *h*, Short process of the incus; *i*, Long process of the incus.

drum membrane with a free, concave margin, forms, with the posterior surface of the membrana tympani, the posterior tympanic pouch (v. Tröltsch)—*recessus membranæ tympani posterior* (Fig. 17, *f*; Fig. 18, *ta*). The anterior pouch, the smaller of the two, is formed by an osseous projection from the neck, the ligamentous and osseous remains of the long process of the malleus, by the chorda tympani, the inferior tympanic artery, and the mucous membrane. The superior boundary of this pouch corresponds with the anterior grey stria of Prussak. The chorda tympani appears at the posterior superior margin of the sulcus tympanicus, communicates with the canalis facialis (Fallopii) by

* Cp. A. Politzer. *Geschichte der Ohrenheilkunde*, vol. i., p. 365.

means of a small canal, and runs along the inferior margin of the posterior tympanic fold over the neck of the hammer to the Glaserian fissure (Fig. 17, *f*).
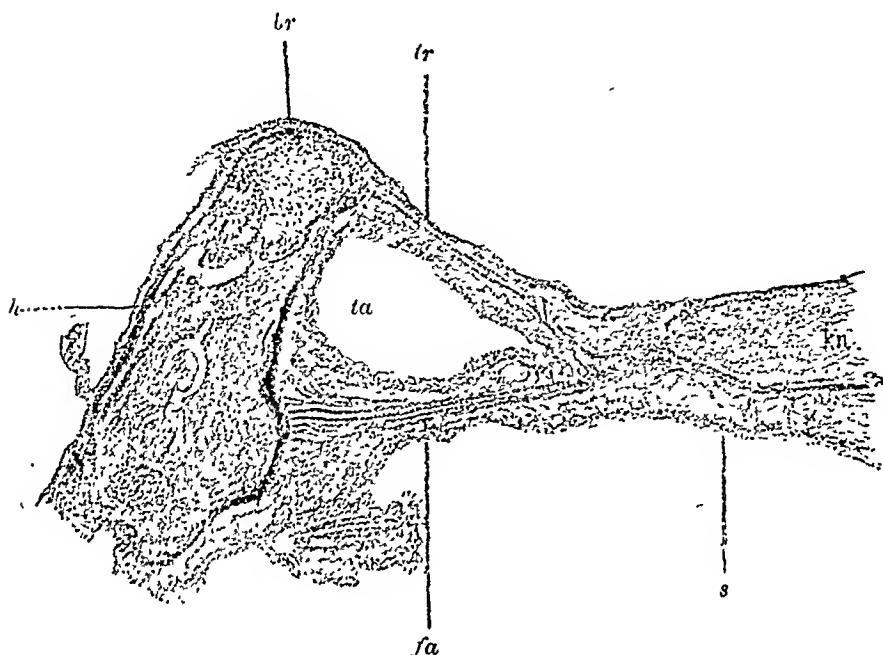
Fig. 18.—Section through the Malleus and the Posterior Tympanic Pouch at the Level of the Short Process of the Malleus.

h, Malleus; *br*, Cartilaginous portion of its short process (Gruber); *tr*, Posterior portion of the tympanic membrane; *fa*, Posterior fold of the tympanic membrane; *ta*, Posterior pouch of v. Tröltsch; *s*, Mucous lining of the tympanic cavity.

The Microscopic Anatomy of the Tympanic Membrane.

The tympanic membrane is composed of three main layers: a middle fibrous (the *lamina propria*), an external cuticular (*stratum cutaneum*), and an internal mucous membrane layer (*stratum mucosum*). The cuticular layer is easily detached from the fibrous, but the internal mucous membrane layer is so closely connected with the membrana propria that it is impossible to separate them.

The cuticular layer, a continuation of the cutis of the external meatus, consists of a stratified squamous epithelium with a Malpighian mucous layer, and contains only a very slight stratum of connective tissue, which seems to bear a constant relation with the vessels and nerves of this layer.

A strongly-developed cutaneous band is found in the new-born, extending from the superior wall of the external meatus to the membrana tympani behind the handle of the malleus; a triangular, translucent space is thereby formed with its apex directed towards the extremity of the handle. Vessels and nerves also extend from the meatus to the membrane along with this cutaneous band, which is composed of connective tissue and elastic fibres (*Prussak's descending fibres*). At the inferior widened extremity of the manubrium, the ligamentous fibres of this bundle radiate, in a star-like manner, towards the periphery, and become interwoven with the fibres of the substantia propria.

2

The middle fibrous layer consists of two separable lamellæ, an external radiating and an internal circular (*stratum radiatum et circulare*). The pale, filamentous, delicate circular fibres of these two layers form a tissue which, according to Gerlach, is midway between the common fibrillated and homogeneous connective tissue of Reichert. The lamina propria is a direct continuation of the periosteum of the annulus tympanicus. The external radiating, partly crossing fibres are attached principally to the enlarged inferior extremity of the manubrium (Fig. 19, *h*), only a few fibres, however, attaching themselves superiorly to its anterior border. They therefore become more dense at the centre, partly because they multiply through splitting (Gerlach), and partly through an accumulation of the fibres at the umbo (v. Tröltsch).

The internal circular lamella consists of fibres which cross the radiating fibres (Fig. 19, *c*). They are lacking at the external periphery of the membrane, and are found within the annulus cartilagineus (*limbus membrani tympani*), which consists of, tough, fibrous connective tissue.

FIG. 19.—SEGMENT OF THE LOWER PORTION OF THE TYMPANIC MEMBRANE.

h, Handle of the malleus; *r*, Layer of radiating fibres (*stratum radiatum*); *c*, Layer of circular fibres (*stratum circulare*).

These fibres are most compact at this place, and become more sparse towards the centre. Superiorly, the circular fibres pass in greater numbers over the external surface of the handle (Prussak). A crossing and amalgamation of the fibres coming from both sides of the manubrium appear to take place only at the inferior third. It is this portion of the handle which is most closely united with the membrana tympani, its connection superiorly being less secure.* Between the fibres of the two layers we find the connective tissue corpuscles of v. Tröltsch. These appear spindle-shaped in the longitudinal, and star-shaped in the transverse section. They show a great similarity to the corpuscles of the cornea, their delicate processes, on the one hand, anastomosing with each other, and, on the other hand, spreading towards the vascular cutaneous and mucous membrane layers from which they draw their nutrition. According to v. Tröltsch, the epithelial cells of the mucous membrane of the drum are supposed to be in direct communication with the corpuscles of the membrana tympani by means of short processes. Watsuji found elastic fibres in the membrana tympani.

The internal or mucous membrane layer of the drum, a continuation of the lining membrane of the tympanum, is closely united with the circular fibrous layer, and consists of a scanty stratum of connective tissue with a covering of non-ciliated squamous epithelium. On the mucous membrane layer, Gerlach found, especially in the new-born, papillæ covered with squamous epithelium and provided with one or more capillary loops; these were analogous to the villi of the intestines.

The fibres of the substantia propria are lacking in the pars flaccida (Shrap-

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* Cp. Politzer, *Die anatom. u. histolog. Zergliederung des menschl. Gehörorgans*. pp. 209 and 210.

nelli); this membrane consists of delicate, irregularly interlacing fibres of connective tissue, covered externally by a thin cuticular layer, and internally by the mucosa of the tympanum. It is penetrated by bloodvessels which are inconstant in their course.

The membrana tympani possesses two vascular networks, separated by the substantia propria, and anastomosing with each other at the periphery; the outer belongs to the connective tissue of the cutis, the inner to the mucous membrane.

The vascular network of the cutis arises from the deep auricular artery, which sends a branch to the centre of the membrane. This arteriole lies between two veins which form a plexus here and there, and descends to the umbo from the posterior superior wall of the meatus behind the manubrium. In the centre of the membrana tympani the arteries and veins com-
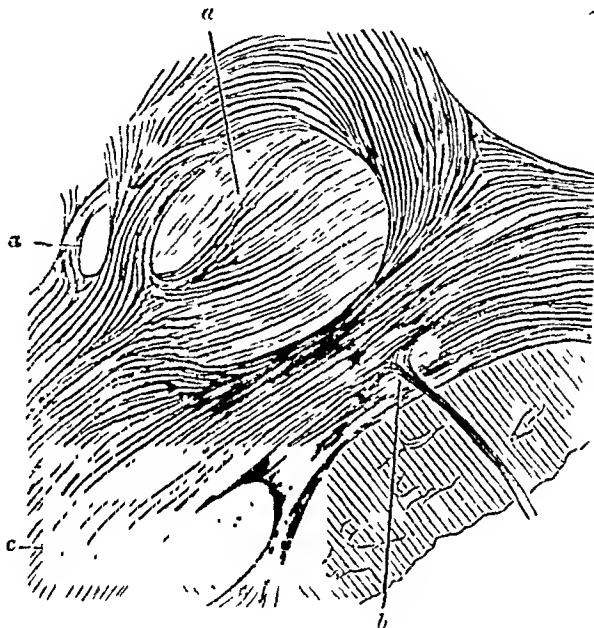
Fig. 20.—Fibrous Framework of the Posterior Segment of the Inner Surface of the Membrana Tympani in the Adult.

a, Great interspace in the framework; *b*, Small interspace, through which a thin process passes; *c*, Arch formed by radiating processes.

municate with a peripheral vascular zone by means of numerous radiating branches; this brings about a communication between these vessels and those of the tympanum (Moos). According to Moos, anastomosing vessels perforate the membrana tympani in the region of the hammer and at other parts. The veins are most numerous at the handle of the malleus and at the periphery. The arterial branches which run along the handle partly enter the venous plexus at this place, and partly radiate towards the peripheral venous zone.

The veins of the cuticular layer of the membrane are connected, partly with those of the external meatus, and partly, through apertures on the periphery of the membrana tympani, with the vessels in the tympanic cavity; these apertures are sometimes of considerable size.

The vascular network on the mucous membrane layer of the drum arises from the vessels of the tympanic cavity, and presents a rather closely meshed capillary system; the latter is developed from an artery which runs parallel

to the handle of the malleus on the internal surface of the membrana tympani (Moos).

According to Kessel (*Stricker's Handbuch,* 1870), the lymphatics of the membrana tympani are arranged, like the arteries, in three layers, anastomosing with each other; on the other hand, Alagna found only a lymphatic network in the membrana propria, which was especially well developed along the handle of the malleus. If the epithelium is brushed off from the mucous membrane layer, there will be found, even under low power, a fibrous framework (Gruber) lying on the substantia propria, which is especially developed on that part situated behind the manubrium. From the membranous expansion of this fibrous framework, which is interrupted here and there (Fig. 20, *a*) by large and small interspaces, there radiate processes which form curves (*c*) of different sizes. These fibres penetrate to the substantia propria, where they become interwoven with the fibres of that layer. According to the investigations of the author, a similar formation is found on the mucous membrane of the tympanic cavity, and cannot therefore be considered a structural peculiarity of the membrana tympani.

The nerves of the membrane arise, according to Arnold, from the superficial temporal branch of the *trigeminus,* and run on the external cuticular layer parallel to the vessels in the form of three or four very delicate, ill-defined branches; they come from the superior wall of the meatus, and pass to the membrane behind the handle of the malleus.

Kessel is supposed to have observed large nervous plexuses and ganglionic swellings around the vessels and between their meshes. A second plexus having multipolar cells is found in the rete Malpighii. The nerves of the cutis divide dichotomously and penetrate the substantia propria, communicating with the nervous plexus of the mucous membrane. Gerlach observed delicate, non-medullated nerves in the superficial layer of the mucous membrane. Forus and Calamida have found, independently of each other, a fine nervous plexus in the mucosa of the membrana tympani.

(*b*) The Superior Wall of the Tympanic Cavity.

The superior wall is formed by an osseous plate continuous with the superior surface of the petrous portion of the temporal bone. This plate forms posteriorly the roof of the *antrum tympanicum,* and anteriorly the roof of the semicanal for the tensor tympani muscle, and of the osseous portion of the Eustachian tube; externally, at the fissura petro-squamosa, it becomes continuous with the lamina interna of the pars squamosa, the latter taking only a small part in the formation of the tegmen tympani. This last-mentioned suture is found on the superior wall of the tympanum in the new-born, and processes of connective tissue containing bloodvessels pass through it from the dura mater into the tympanic cavity (Wagenhäuser). This suture is firmly united in the adult, the connective-tissue processes and vessels having almost entirely disappeared. It is indicated as a jagged furrow on the macerated bone, and is situated for the most part above the osseous meatus. The curved projection of bone placed at right angles to the inferior surface of the tegmen (*crista transversa tympani,* Bezold) serves for the attachment of a fold of mucous membrane, which is connected with the tensor tendon.

The thickness of the superior wall of the tympanic cavity above the head of the malleus is 5–6 mm. This osseous plate is often rather thick and contains many cell-spaces. It is very thin in other cases, and sometimes presents one or more irregular apertures, or it may be defective to a great extent; this is called a dehiscence of the tegmen tympani, and is brought about by an arrest in development or atrophy (Hyrtl). The investigations of the author in regard to dehiscences of the tegmen tympani have shown that these apertures
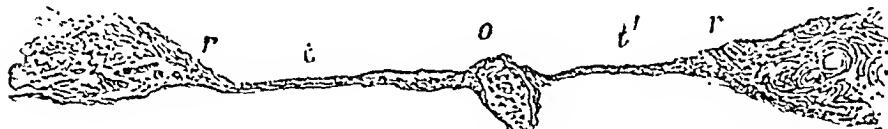
FIG. 21.—CROSS-SECTION OF A DEHISCENT TEGMEN TYMPANI AFTER REMOVAL OF THE DURA MATER.

r, r', Bony margins of the dehiscence; t, t', Dehiscence of the lining membrane; o, Cross-section of an isolated piece of bone embedded in the membrane. (Taken from a specimen in the author's collection.)

are closed by a thin membrane, in which are sometimes enclosed long osseous spines which run in a sagittal direction. The author considers these the remains of the tegmen tympani, and thinks the dehiscence arises only after the development of the temporal bone. The space above the membrana tympani in which the head of the malleus and body of the incus lie is called the superior tympanic cavity (attic of the tympanum, cupola, recessus epitympanicus).

(c) The Inferior Wall of the Tympanic Cavity.

The inferior wall is narrower than the superior; it is bounded behind by the posterior wall, and in front by the gentle elevation of the inferior towards the anterior wall, which is situated below the tympanic orifice of the Eustachian tube. The position and form of the floor of the tympanum depend on the size of the fossa jugularis, the latter being deeper on the right than on the left side. Its surface usually presents ridges and depressions, but is not infrequently smooth and bulged towards the tympanic cavity by the adjoining fossa jugularis. The thickness of this wall is very variable, and, according to Lafite-Dupont, sometimes contains pneumatic spaces. In many specimens of the author's collection, the fossa jugularis reaches up so far that a dehiscence exists between it and the internal auditory canal. A fatal phlebitis and thrombosis of the jugular bulb can be brought about by caries of this wall.

(d) The Posterior Wall of the Tympanic Cavity.

The posterior wall, several millimetres in height, rises rather abruptly from the floor of the tympanic cavity (Fig. 23, e); at its upper part there is a large triangular aperture, which is the means of communication between the tympanum and the mastoid process. The saddle-shaped notch found at the inferior angle of

this aperture (*fossa incudis*) serves for the reception of the short process of the incus. The *eminentia pyramidalis* (*g*) enclosing the stapedius muscle arises from the medial surface of this wall; this eminence, a small, bony process directed forwards, communicates with the facial canal by one or more small fissures; a small, round opening for the exit of the stapedius tendon can be seen at its apex.
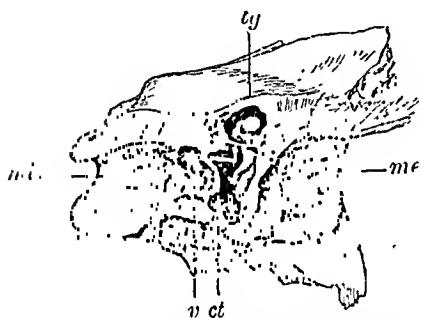
FIG. 22.—FRONTAL SECTION THROUGH THE EXTERNAL MEATUS, TYMPANUM AND THE LABYRINTH OF AN ADULT, THE ANNULUS TYMPANICUS AND MEMBRANA TYMPANI BEING INTACT.

me, Meatus acusticus externus; *ct*, Cavum tympani with the tympanic membrane, the ossicular chain and the tensor tendon; *tg*, Paries tegmentalis (tegmen tympani); *v*, Vestibule; *mi*, Meatus auditus internus. (Left ear.) From a preparation in the author's collection.
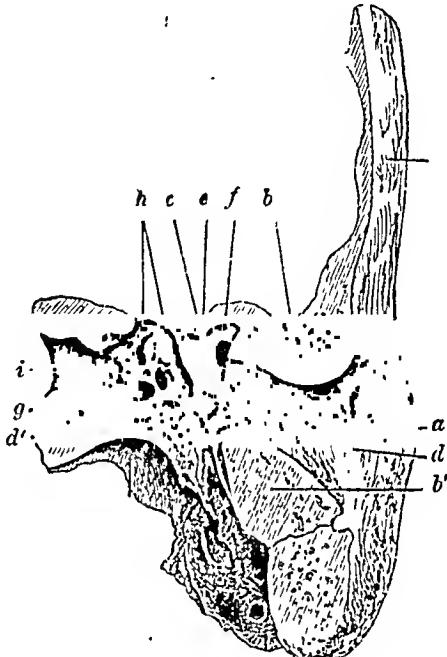
FIG. 23.—VIEW OF THE POSTERIOR WALL OF THE TYMPANIC CAVITY.

a, Meatus; *b*, *b'*, Superior and inferior walls of the meatus; *c*, Superior wall of the tympanic cavity; *d'*, Inferior wall; *d*, Protuberance underneath the eminentia stapedii, caused by the superior extremity of the styloid process; *e*, Posterior wall; *f*, Entrance into the mastoid process; *g*, Eminentia stapedii; *h*, Canalis Fallopiæ; *i*, Internal meatus.

Inferior and somewhat external to the eminentia pyramidalis one often finds a more or less pronounced, irregular protuberance (*d*), which is brought about by a protrusion of the superior extremity of the styloid process—*protuberantia styloidea* (*Arch. f. O.*, vol. x.).

This process, which, according to Gradenigo, is composed of an upper and lower part, originates from the second branchial arch (Reichert), and is mostly cartilaginous after birth, ossifying in the course of the first years of life. The shape of its superior portion in the new-born resembles a club (Fig. 24), the usperior, knobby extremity of which is found inferior to the eminentia

stapedii, and was first described by the author. The rounded extremity of the club (*b*) rests in a cup-shaped depression directed forwards at the external margin of the mastoid antrum. This small depression, ½ mm. in diameter, the author has repeatedly found at the anterior portion of the mastoid process in the macerated temporal bones of the new-born; in such bones, the superior extremity of the styloid process had not yet ossified, and had not yet united posteriorly with the mastoid process. This small cup-shaped depression was first described by the author.*
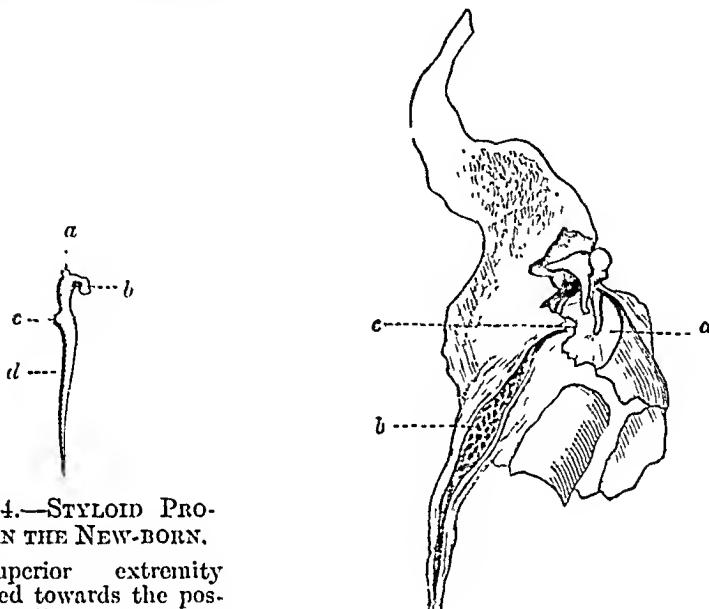
FIG. 24.—STYLOID PROCESS IN THE NEW-BORN.

a, Superior extremity pointed towards the posterior wall of the tympanic cavity (*processus periot. post.*); *b*, club-like extremity pointing backwards; *c*, Short cartilaginous process; *d*, Inferior extremity.

FIG. 25.—SECTION OF STYLOID PROCESS IN THE ADULT.

a, Membrana tympani; *b*, Medullary cavity of the styloid process; *c*, Its superior extremity with the protuberance on the posterior wall of the tympanic cavity.

The ossification of the styloid process often begins before birth at the *processus perioticus posterior*. By carefully opening the sheath of the styloid process in the macerated temporal bone of the new-born, the superior ossified portion is often found firmly united with the above-mentioned small depression.

The author has also succeeded in tracing the styloid process to its uppermost extremity in the adult bone. In carefully-made sections (Fig. 25), the cortical substance of this process was found firmly united with the surrounding bony tissue, but the author could trace the medullary space (*b*) to its superior extremity bordering on the posterior wall of the tympanic cavity.

(c) The Anterior Wall of the Tympanic Cavity.

This wall is formed only by the short, ridgy, oblique plane which arises at the anterior boundary of the inferior wall (Fig. 26, *g'*). At the upper part of this wall, on a level with the entrance of the

* Politzer, *Die anatom. u. histolog. Zergliederung des menschlichen Gehörorgans*, p. 51, Fig. 52, *g*.

mastoid process, a large, irregular, triangular aperture is seen; this is the ostium tympanicum tubæ, which leads into the osseous Eustachian tube, and lies immediately below the semicanal for the tensor tympani muscle. The ridgy, sometimes dehiscent, anterior wall borders immediately on the carotid canal (Fig. 26, *h*), through the elevation of which it is principally formed. A fatal hæmorrhage may occur from caries of this wall, causing erosion of the carotid artery. The walls of this vessel are surrounded by a venous sinus which communicates with the cavernous sinus—*plexus venosus caroticus internus* (Rektorzik).

(*f*) The Inner Wall of the Tympanic Cavity.

The relations of the inner or labyrinthine wall (Fig. 26) are more complicated. On this wall there are two labyrinthine windows, both of which are of great physiological importance. The oval or bean-shaped window (*a*)—*fenestra vestibuli*—which leads into the vestibule, is situated in a deep depression, and receives the foot plate of the stapes. This recess is called the *fossula fenestræ vestibuli (pelvis ovalis)*, and, as we shall see, is very often the seat of pathological changes causing an obstruction to the waves of sound. The greatest diameter of the aperture (3·5–4 mm.) extends from before backwards and downwards; the vertical diameter (1·5–2 mm.) runs obliquely from without inwards and downwards. The plane of the fenestra ovalis is, therefore, just as much inclined to the axis of the external meatus as the drum membrane. The superior margin of this fenestra is convex, the inferior slightly concave. The anterior rounded end is much wider than the posterior, where the superior and inferior margins of the base of the stapes meet in a small, rounded curve.

Below the fenestra vestibuli we see the recess of the fenestra rotunda (*fenestra cochleæ*, Fig. 26, *b*) directed backwards. A small, delicate, somewhat concave membrane, directed towards the tympanum, is found in an obliquely placed groove at its base—*membrana fenestræ cochleæ rotunda* or *membrana tympani secundaria* of Scarpa; this membrane separates the canal of the cochlea from the tympanum. Its height varies from 1·6–3 mm., its width from 1–3 mm. Between this recess and the eminentia pyramidalis there is a depression on the inner tympanic wall, which varies in size in different individuals (*sinus tympanicus*, Steinbrügge); according to Katz, this sometimes forms a rather long, bony canal in the pyramid, and ends in a blind extremity.

The inner wall of the tympanum is strongly bulged between, and a little in front of, the two fenestræ; this is due to the first turn of the cochlea, and is designated the *promontory* (Fig. 26, *c*). Jacobson's nerve runs vertically over the promontory in an open or covered groove (*sulcus promontorii*), and connects the jugular ganglion with the small superficial petrosal nerve. A number of

inconstant, winding furrows in the mucous membrane of the
promontory show the course of the nerve branches which form
the plexus tympanicus.

Above the fenestra ovalis, a portion of the fascial canal can be
seen inclined slightly backwards. This canal commences at the
internal meatus above the place of entrance of the auditory nerve;
it then passes externally above the vestibule into the substance
of the petrous bone, and arriving at the inner tympanic wall, forms
the so-called knee (Fig. 26, *e*); from here the canal continues back-
wards along the inner tympanic wall above the fenestra ovalis,
and at the border between the posterior and inner walls takes a
sudden curve downwards to end at the stylo-mastoid foramen.
That part of the canal which traverses the tympanic cavity some·
times presents dehiscences of varying sizes.
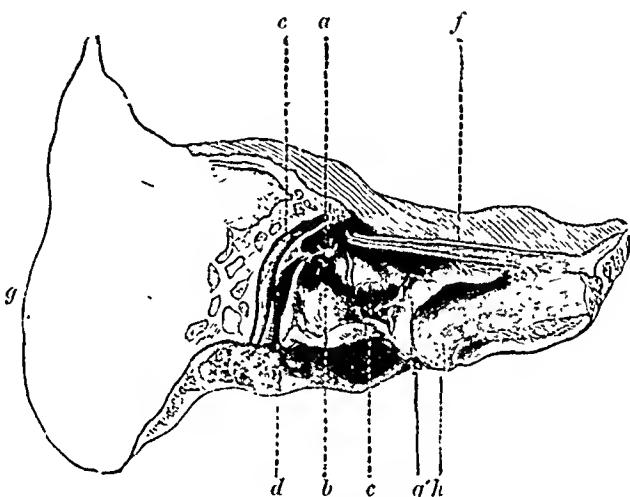
FIG. 26.—INNER WALL OF THE TYMPANIC CAVITY.

a, Fenestra ovalis with the stapes; *b*, Fenestra rotunda; *c*, Promontory; *d*, Musculus
stapedius; *e*, Canalis facialis; *f*, Canal for the tensor tympani; *g*, Mastoid process;
g', Anterior wall of the tympanic cavity; *h*, Carotid canal.

That portion of the Fallopian canal running above the oval
window is bordered posteriorly by an elevation directed towards
the tympanic cavity; this elevation corresponds to the wall of the
horizontal semicircular canal (*prominentia canalis semicircularis
lateralis*), on which, in chronic suppurations of the middle ear,
erosions and fistulæ sometimes form.

The anterior part of the promontory is flatter and narrower,
inasmuch as it is confined between the anterior tympanic wall,
rising obliquely towards the tympanic orifice of the Eustachian
tube and the semicanal for the tensor tympani muscle.

The last-named canal begins at the anterior part of the temporal
bone, in the triangular segment formed by the apex of the petrous
and the interior margin of the squamous portions of the temporal

bone. It lies (Fig. 26, *f*) above the osseous portion of the Eustachian tube, from which it is incompletely, but often completely, separated by a thin, osseous lamella. The canal lies on the border between the internal and superior tympanic walls, and ends at the middle of the facial canal in front of, and above the fenestra ovalis; at this place it presents a spoon-shaped process (*processsus cochlcariformis*) directed externally, over which the tendon of the tensor tympani passes directly across the tympanic cavity to the handle of the malleus (Fig. 30).

(*g*) The Ossicles.

The ossicles form an articulated chain in the tympanic cavity, which extends from the membrana tympani (Fig. 30) to the fenestra ovalis. They conduct the waves of sound from the membrane to the labyrinth; these ossicles are composed of compact and spongy osseous tissue, and are well supplied with vessels. The first of these, the **Hammer** (*malleus*, Fig. 27), resembles a club and measures 7–9 mm. We differentiate an oval head (*a*), with its articular surface directed backwards (*c*), a constricted neck (*b*), an angular handle (*c*) connected with the membrana tympani and strongly inclined inwards, a long process projecting

FIG. 27.—MALLEUS OF A NEW-BORN INFANT.

a, Head; *b*, Neck; *c*, Handle; *d*, Long process; *e*, Articular surface.
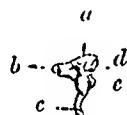
FIG. 28.—INCUS.

a, Body; *b*, Short process; *c*, Long process; *d*, Articular surface; *e*, Inferior toothed process or cog.
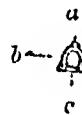
FIG. 29.—STAPES.

a, Head; *b*, Crus; *c*, Foot-plate.

into the Glaserian fissure (*fissura petrotympanica*) (*d*), and a short process, covered with cartilage, and directed towards the external meatus (Fig. 30, *o*). The **Incus** (Fig. 28), the body of which (*a*) resembles the crown of a molar tooth, presents anteriorly surfaces for articulation with the head of the malleus; it possesses two processes, a shorter (*b*) directed backwards towards the mastoid antrum, and a longer (*c*), which is slightly bent and runs downwards and backwards in a direction almost parallel to the handle of the malleus. We find the processus lenticularis (*ossiculum lenticulare Sylvii*) on the long process of the incus, which unites the latter with the head of the stapes. The third ossicle, the **Stapes** (Fig. 29), shows many varieties of form. A hollowed articular surface for the reception of the *ossiculum lenticulare* is seen on its capitulum (*a*). It has two crura, of which the anterior is generally somewhat shorter and less curved than the posterior; they are

separated from the capitulum by a slight constriction, and are united externally in a bow-shaped manner (*collum stapedis*). They are inserted near the inferior margin of the foot-plate, which is convex towards the vestibule (*c*), and corresponds to the bean-shaped outline of the fenestra ovalis. The length (3–3·5 mm.) and width (1·5–2·0 mm.) of the foot-plate vary according to the size of the fenestra ovalis. The average weight of the malleus is 0·023 gramme, of the incus 0·025 gramme, and of the stapes 0·002 gramme (Eitelberg).

Stapedes with one crus (*columella formation*) have been described by some anatomists. Other anomalies in the development of the stapes are a cartilaginous foot-plate, an abnormally large foot-plate, abnormally large crura and head, and a great diminution in the size of the stapes in microtics.
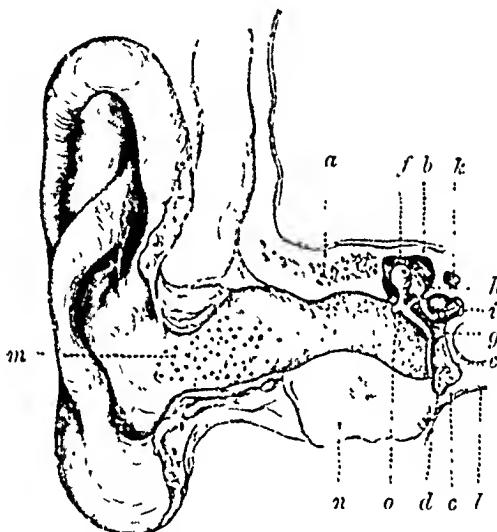
Fig. 30.—FRONTAL SECTION OF THE EXTERNAL MEATUS, MEMBRANA TYMPANI, AND TYMPANIC CAVITY.

a, Cellular spaces in the superior wall of the meatus connected with the middle ear ; *b*, Roof of the tympanic cavity; *c*, Inferior wall; *d*, Tympanic cavity; *e*, Membrana tympani; *f*, Head of the malleus; *g*, Handle of the malleus; *h*, Incus; *i*, Stapes; *k*, Fallopian canal; *l*, Fossa jugularis; *m*, Apertures of glands in the external meatus. (Right ear.)

The head of the malleus is bent at an obtuse angle to its handle. Its neck passes directly into the broad tympanic, rhomboidal surface of the handle; a spiral ledge is seen on the external surface of the neck, from which a strong check ligament extends to the external wall of the tympanum.

The long process of the malleus (*processus anterior, Folii*) passes to the fissura tympano-squamosa (Glaseri); it arises as a narrow, flat, slightly bent osseous lamella from the anterior angle of the internal rhomboidal surface, at the border between the neck and the handle. It is easily recognized in the new-born, but has almost entirely disappeared in the adult, being replaced by a tense ligamentous band extending from the Glaserian fissure to the malleus.

The manubrium, 4·5–5·5 mm. long, resembles a sharp spiculum of bone. A pointed tubercle of considerable size (short process of the malleus) is developed externally at its superior part. If a macerated malleus is ex-

amincd, a small, rough depression is found at tho point of this tubercle corre-sponding to the cartilaginous short process. The slightly curved external edge of the handle, firmly connected with the membrana tympani, takes its origin from the short process, and ends in a broad, spade-like termination. The internal border of the handle arises from the inferior angle of the internal rhomboidal surface. We find between the external and internal edges of the handle two surfaces elevated above the level of the membrana tympani, one directed anteriorly and internally, the other posteriorly and externally.

The embryonic malleus is cartilaginous, and the central part is not only found unossified in the new-born (Moos), but cartilaginous cells are even observed in the adult bone. This has been described by Heinr. Müller in vol. ix. of the *Zeitschrift f. Wissenschaft. Zoologie*, 1858, and depicted on Plate IX. According to Gruber, the greater part of the short process consists of hyaline cartilage, and is to be considered the unossified remnant of the embryonic cartilaginous malleus. The ossicles are supposed to form from the cartilages of Meckel and Reichcrt. In contradistinction to Gradenigo, who believes that the external part of the plate of the stapes is formed by a ring-shaped deposit, Fuchs believes that the entire stapes is developed from the labyrinthine capsule.

Accessory and innumerable ossicles in the tympanum have been observed by Cassebohm, Römer, Rosa and others. Frey saw an incus with a mush-room-shaped exostosis in the middle of its medial surface.

(*h*) The Articulations of the Ossicles (articulationes ossiculorum auditus).

1. **Articulation of the Malleus and Incus** (*articulatio incudo-mal-leolaris*).—An oblong articular surface is found on the posterior part of the head of the malleus, which extends in a spiral manner from above downwards and inwards to the boundary of the neck. It consists of
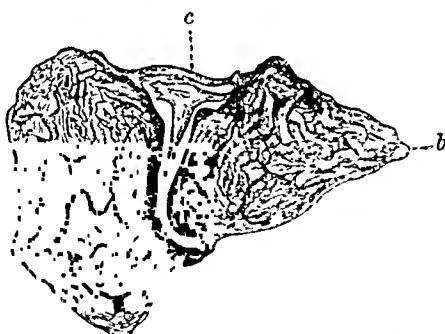
Fig. 31.—Section of the Articulation of the Malleus and Incus.

a, Malleus; *b*, Incus; *c*, Capsular ligament with the wedge-shaped meniscus. (Prepared with hyper-osmic acid.)

two surfaces, which meet in an almost vertical edge, the inferior portion of which is described by Helmholtz as the *cog* of the hammer. The body of the incus also possesses two articular surfaces which correspond with those of the hammer. The superior (Fig. 28, *d*) is directed inwards, the inferior (*e*) out-wards. These articular surfaces are covered by a thin layer of hyaline cartilage. The articulation of these two ossicles is effected by a capsular ligament, which is fastened to the somewhat depressed margins of the articular surfaces, and permits a considerable amount of correlative mobility. A fibro-cartilaginous fold, first described by Pappenheim,[*] projects from the

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[*] Pappenheim, *Spezielle Gewebelehre des Gehörorgans*, 1840.

superior wall of the capsule into the joint as a wedge-shaped meniscus (Fig. 31).

The mechanism of the malleo-incudal articulation is compared by Helmholtz to the contrivance inside a watch-key. As the handle of the malleus
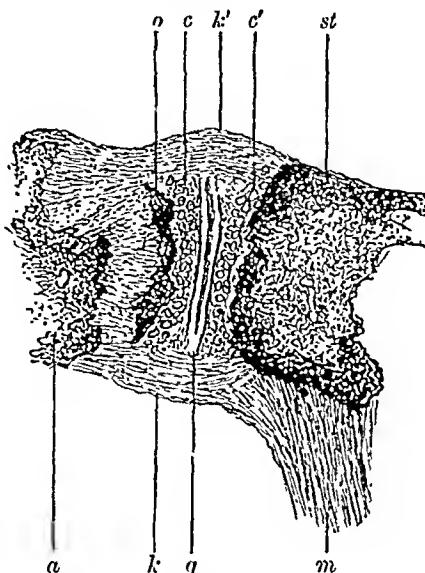
FIG. 32.—SECTION THROUGH THE INCUDO-STAPEDIAL ARTICULATION.

a, Terminal piece of the long crus of the incus, which is connected by fibrous tissue with o, the lenticular process; *st*, Capitulum stapedis; *g*, Cavity of the joint with the meniscus; *c*, *c'*, Hyaline cartilage covering of the articular surfaces; *k*, *k'*, Articular capsule; *m*, Tendon of the musculus stapedius.

moves inwards, its inferior cog (Fig. 27, *e*) catches the corresponding cog of the incus (Fig. 28, *e*), whereby the long process of the latter must follow the motion of the former. If, on the other hand, the handle moves outwards, a
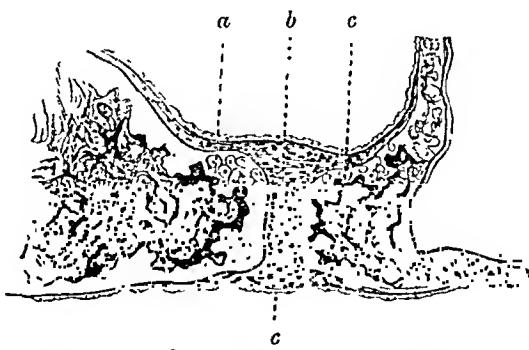
FIG. 33.—SECTION OF THE STAPEDIO-VESTIBULAR ARTICULATION.

a, Margin of the fenestra ovalis covered with a cartilaginous layer; *b*, Margin of the foot-plate of the stapes covered with a cartilaginous layer; *c*, *c*, Section of the ligamentum annulare baseos stapedis.

strong movement of the articular surfaces takes place; the inferior cog of the malleus recedes from that of the incus, whereby the latter follows the motion of the former only to a slight degree.

2. **Articulation of the Incus and Stapes** (*articulatio incudo-stapedia*)
—This joint is formed by the convex globular surface of the processus len-
ticularis, and by the concave articular surface of the capitulum of the stapes,
and is to be regarded as a true joint having a small intra-articular cavity
(Fig. 32). The articular surfaces are covered with a thin layer of hyaline
cartilage, and are united by a capsule containing many elastic fibres, which
permits a considerable lateral mobility.

3. **Articulation of the Stapes and Fenestra Ovalis** (*syndesmosis
tympano-stapedia*).—The tissue connecting the margin of the fenestra ovalis
with that of the foot-plate of the stapes consists of elastic fibres which extend
in a radiating direction, and converge towards the margin of the foot-plate.
This ligament, which is not of equal breadth at all parts of the circumference
of the oval window, is derived from the periosteum of the bone encircling the
fenestra ovalis, and assumes the *rôle* of the periosteum at the foot-plate of the
stapes. Toynbee and Magnus have shown that the margin of the foot-plate
and that of the fenestra ovalis are covered with a thin layer of cartilage; this,
according to Eysell, also lines the vestibular surface of the stapes, and encloses
the periphery of the foot-plate in a hook-shaped manner.

(*i*) The Ligaments of the Ossicles.

Several ligamentous bands are still to be enumerated in addition to those
capsular ligaments mentioned above; these extend between the walls of the
tympanic cavity and the ossicles, retaining them in their position, and acting
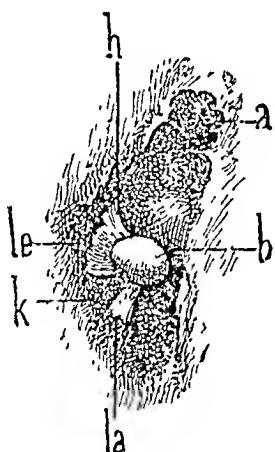
FIG. 34.—LIGAMENTUM MALLEI
ANTERIUS ET EXTERNUS.

b, Head of the malleus; *la*, Ligamentum
mallei anterius; *le*, Ligamentum mallei
laterale (ext.); *h*, Its posterior portion;
k, Osseous tip of the spina tympan.
post. (major), projecting between the
ligament. mall. ant. et extern.; *a*, An-
trum tympanicum (mast.). From a
preparation in the author's collection.
(Right ear.)
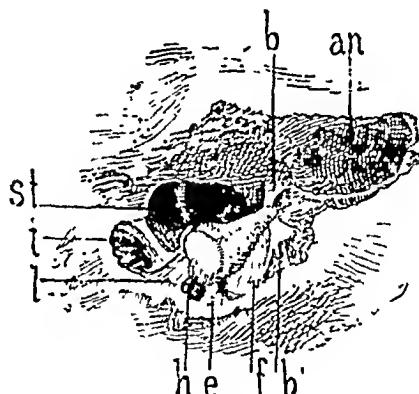
FIG. 35.—LIGAMENTOUS APPARATUS
OF THE MALLEUS AND INCUS.

h, Head of the malleus; *l*, Ligament.
mall. ant.; *c*, Ligament. mall. laterale;
f, Outer fold of the incus; *b*, Inner,
b', Outer portion of the ligament. incud.
post.; *t*, Tendon. of the musc. tens.
tymp.; *st*, Incudo-stapedial articula-
tion; *an*, Antr. tymp. (mast.). From
a preparation in the author's collec-
tion.

as check-bands in case of two great excursions. 1. The *ligamentum mallei
superius* is a round band, which extends from the superior wall of the
tympanic cavity to the head of the malleus; it acts as a check against an
excessive external rotation. 2. The *ligamentum mallei anterius* (Fig. 34, *la*)

is a short, very broad, fibrous band, which encircles the long process of the malleus, and is inserted into those parts of the head and neck which are directed forwards. It must be regarded as the residuum of the embryonic *processus Meckeli* of the malleus. This is proven by the investigations of Sapolini and Verga, who described a ligamentum malleo-maxillare, which extends from the malleus, through the Glaserian fissure, to the inferior maxilla. 3. The *ligamentum mallei laterale* (Helmholtz) (Fig. 34, *le*) extends between the crista capitis mallei and the external tympanic wall above the Rivinian segment; it also acts as a check against an excessive external rotation. Helmholtz calls the posterior fibres of this ligament the *ligamentum mallei posterius*. If a line passing through the latter is prolonged forwards through the malleus, it would intersect the middle fibres of the anterior ligament, and as the axis on which the malleus turns passes through these two fibrous prolongations, Helmholtz calls them the ligaments of the axis of the malleus. 4. *Ligamentum incudis posterius* (Fig. 35, *b*, *b'*). The short process
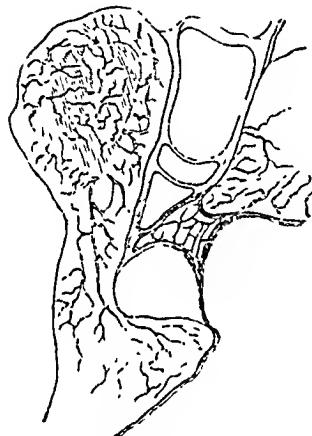
FIG. 36.—SYSTEM OF CAVITIES BETWEEN THE MEMBRANA TYMPANI AND THE NECK OF THE MALLEUS.
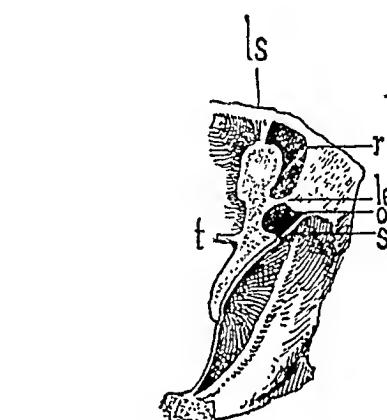
FIG. 37. — PRUSSAK'S SPACE. SECTION THROUGH THE TYMPANIC MEMBRANE, MALLEUS, UPPER AND OUTER TYMPANIC WALL OF A DECALCIFIED PREPARATION.

ls, Ligament. mall. super.; *le*, Ligament. mall. lat.; *s*, Membrana Shrapnelli; *o*, Prussak's space; *r*, System of cavities between the body of the malleus and incus and the external tympanic wall; *t*, Tendon of the musc. tens. tymp. From a preparation in the author's collection.

of the incus, covered with a thin layer of fibrous cartilage, rests in the saddle-shaped depression on the posterior tympanic wall at the entrance of the antrum, and is connected with the tympanic wall by means of fibrous tissue on its external and internal side; that band extending between the short process of the incus and the external margin of the articular facet is strongly developed (*b'*.)

The attic or cupola of the tympanum (*cavum epitympanicum*) (p. 12) is divided into two parts by the articulation of the malleus and incus. That part lying between the malleo-incudal articulation and the external tympanic wall is called by the author the *external attic* (Kretschmann's *Hammer-Ambos-Schuppenraum ;* Gellé's *Logette des Osselets*). This is formed above by the ligamentum mallei superius and the superior malleo-incudal fold, and seems therefore to be more or less anatomically separated from the internal attic. The external attic is again divided into an upper (Fig. 38, *ae*) and a lower space (*P*). The latter is known as *Prussak's space*, and is bounded internally
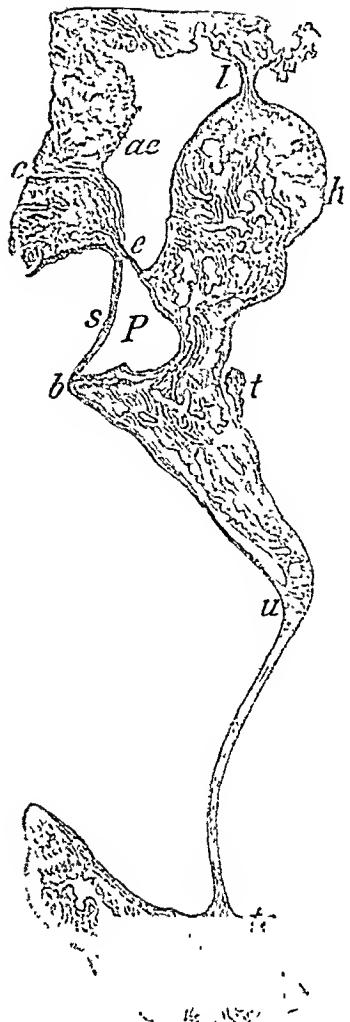
FIG. 38.—SECTION THROUGH
THE HAMMER, MEMBRANA
TYMPANI AND EXTERNAL
ATTIC.

h, Head of the hammer; *te*, An-
nulus tendinosus of the mem-
brana tympani; *b*, Processus
brevis; *u*, Umbo; *t*, Chorda
tympani; *l*, Ligament. mall.
sup.; *e*, Ligament. mallei ext.;
s, Membrana flaccida (Shrap-
nelli); *ae*, External attic; *P*,
Prussak's space, recessus epi-
tympan.; *c*, Vascular canal
between the external attic and
the osseous meatus.

by the neck of the malleus, inferiorly by the
upper surface of the processus brevis (*b*),
externally by the pars flaccida Shrapnelli (*s*),
and superiorly by the ligamentum mallei
externus (*e*), and a system of cavities; these
often extend some distance superiorly, and
were first described by the author (Fig. 36)
(*Wien. med. Wochenschr.*, 16, 1870). This
membranous framework, also observed by
Schmiegelow, is formed by a number of
inconstant folds and bridges of mucous
membrane, which run from the external
surface of the malleo-incudal body to the
opposite tympanic wall. The most constant
of these is the external malleo-incudal fold,
which often divides the external attic into
three overlying spaces. Prussak's space
communicates on the one hand with the
upper part of the attic, and on the other
with the posterior tympanic pouch; it opens
posteriorly into the tympanum by a small,
round, or slit-like orifice which is hidden by
the incus.

Experiments, which the author carried
out on normal organs of hearing, showed
that quicksilver, poured into the external
meatus, sometimes flowed into the posterior,
seldom into the anterior tympanic pouch
after an artificial perforation of the pars
flaccida; this is a proof of the variable
communications of Prussak's space with the
adjoining parts of the tympanic cavity.
The external attic, the anatomical relations
of which are made clear in the accompany-
ing figure (Fig. 38), is occasionally the seat
of a protracted suppuration, with perfora-
tion of Shrapnell's membrane. The height
of the attic from the Rivinian segment to
the tegmen tympani varies from 3–6 mm.
(Klingel, *Z. f. O.*, 1891).

(*k*) The Intratympanic Muscles (musculi ossiculorum auditus).

1. The Tensor Tympani Muscle.—

This muscle arises in front of the
anterior orifice of the semicanal for
the tensor tympani muscle, on the
osseous wall of that portion of the
petrous bone adjacent to the carotid
canal, and from the cartilaginous
Eustachian tube. The round tendon
of this penniform muscle leaves the canal at the *processus
cochleariformis*; it then runs straight across the tympanic cavity
in a direction almost at right angles to its belly (Fig. 39, *s*), and

is inserted at the inner margin of the manubrium at the anterior edge of its rhomboidal surface, and in an oblique direction to its longitudinal axis.

The tendon of the tensor tympani, which can be traced some distance in its canal, lies in a sheath in its free course (*Toynbee's tensor ligament*). According to Henle, this sheath is connected to the tendon by considerable prolongations of connective tissue. The anterior portion of this muscle is sometimes united with the tensor veli palatini, either directly or by fibrous tissue (L. Meyer).

2. The **Stapedius Muscle** arises from the eminentia pyramidalis (Fig. 40, *ms*). It is pyriform on longitudinal section, and generally prismatic, with rounded edges, on transverse section. The fibres, springing from the muscular sheath, extend from the floor and
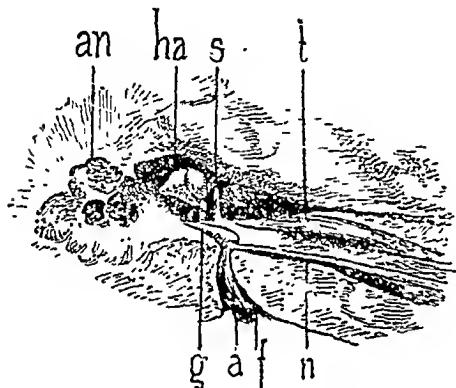
FIG. 39.—VIEW OF THE TYMPANIC CAVITY AFTER REMOVAL OF THE TEGMEN TYMPANI.

ha, Malleo-incudal articulation; *t*, Musc. tens. tymp.; *s*, Tendon of the musc. tens. tymp. passing across the tympanum; *f*, Nerv. facialis; *g*, Genu nervi facialis; *n*, Nerv. petros. superf. major; *a*, Nerv. acusticus; *an*, Antrum mast. From a preparation in the author's collection. (Right ear.)

FIG. 40.—POSTERIOR PORTION OF THE INNER TYMPANIC WALL.

st, Stapes; *cs*, Capitulum stapedis; *ms*, Musc. stapedius in the cavitas stapedii, with its tendon inserted at the capitulum; *p*, Promontory; *f*, Nervus facialis; *v*, Vestibule laid open. From a preparation in the author's collection. (Right ear.)

lateral walls of the cavity, upwards and towards the middle of the muscle, and merge into a tendon, the tissue of which can often be traced inferiorly, beyond the middle of the muscle. This delicate tendon passes into the tympanum through an aperture at the apex of the eminentia pyramidalis, and is inserted at the head of the stapes. The outermost fibres of the tendon (Fig. 32) proceed to the capsular ligament and the ossiculum lenticulare. According to Zuckerkandl, adipose tissue is found between the muscle fibres of the tensor and the stapedius. Reinitz (*A. f. O.*, vol. lxx.) found in the muscle so-called ' muscle-spindles,' which, according to physiologists, is the organ of muscular sense.

3

A direct communication exists in the new-born between the inferior part of the eminentia stapedii and the Fallopian canal; in the adult, one or more long fissures are often found between the two. The nerve of the stapedius arises from the facial and passes either through one of these fissures, or through a separate small aperture to the muscle.

The difference of opinion whether the motor elements of the nerve to the tensor tympani, arising from the otic ganglion of Arnold, belong to the-facial (Longet) or to the trigeminus (Luschka), induced the author to investigate the matter experimentally in Professor Ludwig's laboratory.*

In these experiments, which were carried out on recently killed dogs, the intratympanic muscles were made to contract by electrical stimulation of the cranial nerve roots and showed the following:

1. That the tensor tympani is supplied by the motor portion of the fifth cranial nerve.

2. That the central fibres of the stapedius are supplied by the seventh cranial nerve.

(*l*) The Lining of the Tympanic Cavity.

The lining membrane of the tympanic cavity in the adult appears as a thin transparent pellicle; it is intimately connected with some parts of the osseous walls, especially the inferior and superior, while on other parts, for example the promontory, it is more easily detached. This membrane shows a great similarity to the mucous membrane of the accessory sinuses of the nose. The epithelium of the mucous membrane in the inferior portion of the tympanum is of the ciliated cylindrical variety, and gradually passes into the ciliated squamous variety in the superior part of this cavity.

The connective tissue stratum of this mucous membrane (Fig. 41), in which bloodvessels, lymphatics and nerves ramify, is composed of two layers, the inferior of which must be considered as the periosteum of the osseous wall. The author found (*Arch. f. O.*, vol. v.), especially on the ridgy inferior and anterior walls, networks of fibres in the superior layer of this stratum similar to the framework of the membrana tympani.

The lining membrane of the tympanic cavity is a direct continuation of the mucous membrane of the pharynx and of the Eustachian tube, and cannot, therefore, be considered a serous membrane. According to the investigations of the author, there is sometimes found a variable amount of glandular elements only in the anterior part of the tympanic cavity in the region of the tube. These are entirely lacking in the posterior part of the tympanum, and in the lining membrane of the mastoid cells.† This anatomical condition was confirmed by Manasse.

The following vascular mucous membrane folds, between the ossicles and the tympanic walls, are to be noticed: the inconstant lateral, malleo-incudal fold, running from the incus to the inner tympanic wall; a vertical fold stretching from the external surface of the malleo-incudal body to the external attic wall, through which the upper part of the external attic is divided into

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* Compare the complete account of these experiments given in the reports of the *Wiener Academie der Wissenschaften*, March 14, 1861.

† Ganfrini (*Anat., Anz.*, vol. xxvi.), found in some mammals deposits in the mucous membrane which resembled glands.

an anterior and posterior compartment; another fold, from the crista transversa to the tendon of the tensor, and a duplicature extending from this to the anterior tympanic pouch; the stapes fold, which runs between its crura (*membrana obturatoria stapedis*), and also between the posterior crus and tendon of the stapedius; and finally an inconstant membranous framework, which, as the author was the first to prove, extends from the malleo-incudal body and external attic to the mastoid antrum. Purulent inflammations of the external attic may therefore extend to the mastoid antrum by means of this framework, and *vice versa*, from the latter to the attic and Prussak's space.

The author found, besides the above-mentioned folds of mucous membrane, a number of inconstant connective tissue prolongations, which were formerly considered as pathological products, but which he was the first to show were the residuum of the gelatinous connective tissue filling the middle ear in the fœtal state (*Beleuchtungsbilder des Trommelfells*, 1865). One often finds

FIG. 41.—SECTION OF THE LINING MEMBRANE OF THE INNER WALL OF THE TYMPANIC CAVITY.

a, Epithelium; *b*, Section of a bloodvessel in the stratum of connective tissue, from which a branch penetrates into the funnel-shaped depressions of the bone; *c*, Bloodvessel on the surface, penetrating into the bone; *d*, *d*, Osseous wall; *e*; *e*, Funnel-shaped depressions in the bone, into which the stratum of connective tissue of the lining membrane penetrates; *f*, Section of a large nerve trunk in the stratum of connective tissue of the lining membrane. (Decalcified and prepared with osmic acid.)

such bridges and bands between the membrana tympani and inner tympanic wall, and also between the manubrium, long process of the incus and stapes. String or band-like connections are almost always present between the crura of the stapes and the walls of the pelvis ovalis. In inflammatory processes, these favour the formation of adhesions in the neighbourhood of the crura The author discovered with the aid of the microscope peculiar formations upon these connective tissue structures, the existence of which was formerly unknown. These (Fig. 42) most often appear oval, sometimes constricted in one or more places, pyriform and at times triangular; sometimes both forms are combined in one specimen. These small bodies, covered with epithelium, show macroscopically, as well as in section, a stratified fibrous structure running parallel to the external contour; small spindle-shaped bodies are found between these layers.

A fibrous stalk of varying size, arising with a broad base from the membranous support, enters the rounded extremity of this body and passes

through it; it then issues from its other extremity and is inserted into a membrane or an opposite-lying wall. Sometimes a stalk traverses several of these bodies or divides into two upon emerging. The size of these bodies varies from 0·1–0·9 mm. and upwards. The author found these bodies most frequently in the posterior portion of the tympanic cavity, in the antrum, in the superior tympanic space, on the membrana tympani, in Prussak's space and in the fossula fenestræ vestibuli. These bodies, discovered by the author (*Wien. med. Wochenschr.*, November 20, 1863), were later substantiated by Kessel and others.

The mucous membrane of the tympanum in the new-born is remarkable for its vascularity and for the great thickness of its tissue (Brunner). Densely-packed papillæ are often found on smooth portions of the adult tympanic cavity, as, for example, on the promontory, and are similar in structure to those found on the membrana tympani (p. 19). Moos and the author found vascular papillæ and villi in the mucous membrane of the tympanum, which were covered with cylindrical epithelium. The great tumefaction and vascularity are in accordance with the evolutional processes which take place in the middle ear of the fœtus and after birth. The fœtal tympanic cavity is filled with a gelatinous mass which, on microscopic examination, presents the character of undeveloped connective tissue with spindle-shaped cells in a structureless, gelatinous, fundamental substance.
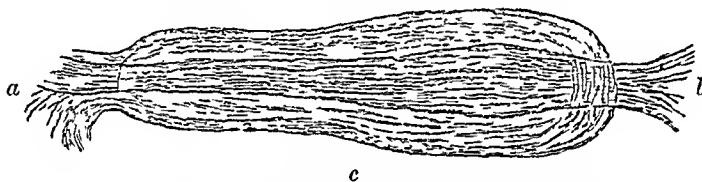
FIG. 42.—OVAL BODY IN THE MIDDLE EAR.

a, Entrance of the stalk; *b*, Exit of the stalk; *c*, Constricted part of the body.

This tissue is called by v. Tröltsch the mucous membranous pad of the labyrinthine wall, and frequently shows the process of resorption and degeneration even before birth. A rapid absorption of this pad ensues after birth owing to the entrance of air into the tympanic cavity. A pus-like mass is very often found completely filling the tympanum of the new-born. The statement that in all such cases there was a former middle-ear suppurative inflammation (v. Tröltsch) has never been positively established. The frequent appearance of microbes in this fluid cannot be considered a proof of such an inflammation, inasmuch as the investigations of Chwostek have shown that after death a rapid invasion of micro-organisms into the cavities of the body and into the tissues takes place. The opinion which the author advanced, that in most of these cases it was a degenerative process and not a purulent inflammation, was confirmed by the bacteriological investigations of Gradenigo and Penzos (*Z. f. O.*, vol. xxi., p. 298).

(*m*) The Vessels and Nerves of the Tympanic Cavity.

The **arteries** of the tympanum arise from the various arteries in its neighbourhood. The anterior and middle parts are supplied (1) by the tympanic branch of the internal maxillary, which enters through the fissura tympano-squamosa; (2) by the ascending pharyngeal, a branch of the external carotid: it penetrates the floor of the tympanum, runs over the promontory to the tegmen and anastomoses with the middle meningeal; (3) by branches of the middle meningeal, which enter through the hiatus canalis Fallopii and the fissura petro-squamosa; (4) by the internal carotid, which sends several

small branches of the ramus carotico-tympanicus through small orifices in the walls of the carotid canal. The stylo-mastoid artery, which enters the Fallopian canal, supplies the neurilemma of the facial nerve, the stapedius muscle, and also sends small branches to the lining membrane of the tympanic cavity and mastoid cells; it anastomoses with the middle meningeal through the superior aperture of the aqueduct of Fallopius. Lewin (*A. f. O.*, vol. lxx.) describes a case in which, in an adult, the stapedius artery was persistent.

The **veins** of the cavum tympani empty into those of the external meatus by means of numerous anastomotic branches which perforate the membrana tympani; into the venous plexus (Rektorzik, Heike), which surrounds the internal carotid in its canal; into those of the dura mater through the fissura petro-squamosa, and finally into the venous plexus surrounding the maxillary joint. The veins of the lining membrane are very tortuous, and show considerable pouch-like dilatations here and there.

In regard to the relation of the bloodvessels of the mucous membrane to the osseous walls of the tympanic cavity, the author showed anatomically that vascular connections exist between the middle ear and the labyrinth through the inner tympanic wall.* The author found in microscopic sections of the promontory that the bloodvessels of the mucous membrane of the middle ear are accompanied by large connective tissue prolongations; the latter penetrate the funnel-shaped canals of the bone (Fig. 41, *e, e*), and enter into communication with the bloodvessels of the osseous wall, by means of which they come into direct union with the vessels of the lining membrane of the labyrinth. These specimens had been treated with osmic acid and decalcified. The points of entrance of the vessels into the bone are recognizable with the naked eye as black dots on the surface. This relation, confirmed by Manasse and Shambough, of the tympanic mucous membrane to the osseous wall is of special importance, inasmuch as inflammations of this membrane can produce transitory or permanent hyperæmia, and disturbances of nutrition in the bone and in the labyrinth.

According to our present knowledge, little is known of the **lymphatics** of the cavum tympani.

The **nerves** of the lining membrane arise from the sensory fibres of the trigeminus, the sympathetic and the glosso-pharyngeal. The tympanic branch, which arises from the latter, is the most highly developed of all the nerves of the tympanum. It passes from the fossa jugularis through an opening in the inferior tympanic wall, and extending upwards in a groove on the promontory, anastomoses with the small superficial petrosal nerve. This is known as Jacobson's nerve, and contains isolated ganglion cells which have been demonstrated by the investigations of Pappenheim, Kölliker, and Krause.† W. Krause traced a rather large branch arising from the plexus tympanicus, which ran to the cartilaginous Eustachian tube. The author has repeatedly seen such a branch arise directly from Jacobson's nerve.‡

The sympathetic nerves of the lining membrane of the middle ear arise from the sympathetic plexus accompanying the carotid artery. Several small branches of this plexus enter the tympanic cavity through orifices in the canal, as the nervi carotico-tympanici. These, in conjunction with the small branches of Jacobson's nerve and the small superficial petrosal nerve (arising from the trigeminus), form the tympanic plexus in the anterior portion of the tympanic cavity. Smaller nerve branches arise from the plexus, which supply the entire lining membrane of the middle ear, and in which

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* *Ueber Anastomosen zwischen den Gefässbezirken des Mittelohrs und des Labyrinths, A. f. O.*, vol. ix.

† *Zeitschr. für rat. Medizin,* 1866.

‡ Cp. Bischoff jun., *Mikroskopische Analyse der Anastomosen der Kopfnerven.* München, 1865.

one finds, in the region of the fenestra ovalis, clusters of ganglion cells. Besides the latter, there is a delicate, ramifying network of nerve-fibres which spreads partly above and partly below the vessels, and forms ganglionic swellings where several fibres meet.

2. The Eustachian Tube (tuba auditiva).

The Eustachian tube, which connects the tympanic cavity with the pharynx, brings about an interchange of air between the external atmosphere and the tympanum, and is composed of an osseous and membrano-cartilaginous part. The axis of the canal

FIG. 43.—EUSTACHIAN TUBE AND TYMPANIC CAVITY.

a, Membrana tympani; b, Head of the malleus; c, Lower end of the handle of the malleus; d, Body of the incus; e, Short process of the incus; f, Tensor tympani; g, Ostium pharyngeum tubæ; h, Isthmus tubæ; i, Ostium tympanicum tubæ. (Right ear.)

assumes, according to Henle, an almost diagonal position to the horizontal between the transverse and sagittal planes. Its axis forms an angle of 135° with the transverse axis of the auditory canal, and an angle of 40° with the horizontal. Its tympanic orifice is about 2·5 cm. higher than its pharyngeal opening.

The length of the canal measures 34–36 mm., of which the carti-

laginous portion forms nearly two-thirds. The very narrow, slit-like part, the so-called *isthmus tubæ*, situated in the cartilaginous section in front of its point of union with the osseous portion, measures, according to the corrosive specimens of Bezold, 3 mm. in height and not more than ¼ mm. in width. Its distance from the pharyngeal orifice averages 24–26 mm.

1. The Osseous Portion of the Eustachian Tube (pars ossea tubæ auditivæ).

The lateral osseous portion of the tube is a prolongation of the anterior portion of the tympanic cavity directed medially; it is bounded above by the tegmen tympani and the canal for the tensor tympani, below and medially by the carotid canal.

Fig. 44.—Sagittal Section through the Entire Middle Ear of an Adult (Inner Half).

op, Ost. pharyng. tubæ; *te*, Canalis tubæ audit.; *ot*, Ost. tymp. tubæ; *tp*, Musc. tens. tymp.; *p*, Promontory with the nervus tympanicus; *u*, Inferior wall of the tympanic cavity; *st*, Stapes; *sp*. Musc. stapedius; *f*, Facial nerve; *an*, Antrum mastoid; *w*, *w'*, Mastoid cells. From a preparation in the author's collection. (Left ear.)

The boundary between the tube and the tympanum is not sharply defined, as the superior and lateral walls of the latter merge without interruption into the former. The boundary is more sharply defined inferiorly where the obliquely rising anterior wall of the tympanum curves towards the inferior wall of the osseous tube (Figs. 43 and 44, *ot*). The tympanic orifice of the Eustachian tube lies above this place at the level of the upper third of the tympanum; it is irregularly defined and inconstant in size, the height of which measures 4·5 mm., the breadth 3·3 mm. The lumen of the osseous canal—the diameter of which, according to Henle, is about 2 mm.—diminishes slightly at its place of union with the

one finds, in the region of the fenestra ovalis, clusters of ganglion cells. Besides the latter, there is a delicate, ramifying network of nerve-fibres which spreads partly above and partly below the vessels, and forms ganglionic swellings where several fibres meet.

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FIG. 43.—EUSTACHIAN TUBE AND TYMPANIC CAVITY.

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laginous portion forms nearly two-thirds. The very narrow, slit-like part, the so-called *isthmus tubæ*, situated in the carti-laginous section in front of its point of union with the osseous portion, measures, according to the corrosive specimens of Bezold, 3 mm. in height and not more than $\frac{1}{4}$ mm. in width. Its distance from the pharyngeal orifice averages 24–26 mm.

1. The Osseous Portion of the Eustachian Tube (pars ossea tubæ auditivæ).

The lateral osseous portion of the tube is a prolongation of the anterior portion of the tympanic cavity directed medially; it is bounded above by the tegmen tympani and the canal for the tensor tympani, below and medially by the carotid canal.

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cartilaginous portion; in transverse sections it shows an irregular triangular contour, brought about by angular projections (L. Meyer*).

2. The Cartilaginous Portion of the Eustachian Tube (cartilago tubæ auditivæ).

The cartilaginous, medial part of the tube is attached to the rough, irregular, oblique margin of the anterior extremity of the osseous portion; it reaches further up laterally than medially, because the lateral wall of the osseous portion is shorter than the medial wall. The cartilaginous tube is not, however, cartilaginous in its whole circumference, but is partly made up of a membrane which completes the groove-shaped cartilage into a canal.

The cartilaginous plate, turned in at its superior margin, forms, near its insertion into the osseous part, a narrow groove, the anterior external wall of which is broader than the posterior internal; further down, however, a few millimetres from the osseous tube (*at the spina angularis*, Henle), the posterior wall, directed more superiorly, increases rapidly in height; the anterior wall, directed more inferiorly, which is the upper margin of the cartilaginous plate, forms a narrow, turned-in strip (Fig. 45, *b*), which roofs over the tube in its entire length. The cartilaginous tube is about 25 mm. in length, and has the appearance of a triangle, the apex of which is at the osseous tube, while the base is prominent as a rounded swelling on the lateral pharyngeal wall. That portion of the cartilage near the osseous tube is attached to the basilar fibro-cartilage, and is less movable than the inferior broad portion, which stands away from the base of the skull. The cartilage itself is composed of the hyaline variety superficially and has a fibrous base in its deeper layers; it frequently shows a number of irregular fissures and clefts, and sometimes disruptions into several pieces. Moos and Zuckerkandl describe several accessory cartilages of the fibrous variety in the region of the cartilagino-membranous portion.

The length of the Eustachian tube in the new-born measures 18–20 mm. of which 8–9 mm. belong to the osseous and 11–12 mm. to the cartilagino-membranous portion. Its tympanic orifice is comparatively large, and lies somewhat lower than in the adult; on the other hand, the pharyngeal orifice, also lying comparatively deeper, appears nearer the choanæ and floor of the nose. The orifice is indicated only by a slightly curved fissure, and its posterior lip forms a hardly noticeable projection on the lateral wall of the pharynx. The tube in the new-born is also comparatively shorter and wider; this condition is of practical importance, in so far as obstructions in it caused by swelling of the mucous membrane may be more easily removed by an inflation of air.

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* Cp. A. Politzer, *Die anatom. und histolog. Zergliederung des menschlichen Gehörorgans*, p. 43.

The relation of the membranous portion to the cartilaginous plate is most clearly shown by sections cut at right angles to its long axis. In such sections (Fig. 45) we see the medial cartilaginous plate (*a*) turned in at its superior part in the shape of a hook (*b*). The membranous portion of the tube commences at the rounded end of this hook; it is delicate and thin near the cartilage, increasing, however, in thickness inferiorly, and is surrounded nearly in its whole extent by a stratum rich in glands as well as by strongly developed adipose tissue; the latter varies in different individuals (Ostmann). The membranous portion which merges below into the salpingo-pharyngeal fascia forms, according to v. Tröltsch, the smaller part of the circumference of the tube; it also forms, in conjunction with the cartilaginous hook, the lateral anterior wall of the cartilagino-membranous tube (*i*) as well as its base (*d*). The portion near the pharyngeal orifice is much thinner than that near the osseous tube, where it receives fibrous tissue from the spina angularis of the sphenoid, and maintains a certain thickness and resistance through the insertion of a small piece of cartilage (Zuckerkandl).
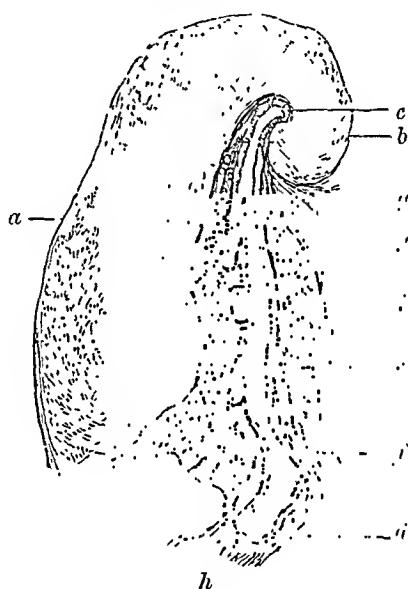
FIG. 45.—TRANSVERSE SECTION OF THE CARTILAGINOUS EUSTACHIAN TUBE, WITH ITS S-SHAPED CLEFT.

a, Central cartilaginous plate; *b*, Cartilaginous hook; *c*, Space below the cartilaginous hook; *d*, Base of the Eustachian tube; *e*, *e'*, Folds of mucous membrane; *f*, Cylindrical epithelium; *g*, Musc. tensor palat. mollis; *h*, Musc. levator palat. mollis.

Through the hook-like twist of the cartilage at the upper margin of the cartilaginous plate a space is formed which varies in size in different parts of the tube. Near the osseous portion the walls of this space do not come into contact. The medial and lateral walls of the tube are, however, in close contact in its middle portion, and only at the pharyngeal orifice do they again stand somewhat apart.*

The mucous membrane of the membranous tube has many folds in its lower portion. According to Moos, these folds form a bulging immediately behind the ostium pharyngeum, through which the tube is closed when at rest. The folds become more numerous in the superior portion of the tube.

* Cp. v. Tröltsch, *Arch. f. Ohrenheilk.*, vol. ii., and Moos, *Arch. f. Augen. und Ohrenheilk.*, vol. i.

Lining of the Eustachian Tube.—Tho walls of the Eustachian tube are covered by a glandular mucous membrano with a ciliated cylindrical epithelium. The lining membrano of tho osseous tube is smooth, and closely united with tho periosteum. Tho mucous membrano of the cartilaginous plate is very strongly developcd on the medial wall, and a greot number of acinous glands discharge on its surface (Fig. 45, *i, e*). Theso glands extend nearly to the perichondrium, but sometimes can be traced, cspccially near the pharyngeal orifice, through the inconstant fissurcs in the cartilage into the surrounding connective tissue. The glands are most numorous near tho pharyngeal orifice, and are less abundant in the osseous portion near the tympanic cavity; they are entirely lacking in the mucous mombrane imme- diately below the so-called hook. Gorlach found lymphoid tissue in the mucous membrane of tho cartilaginous portion of the Eustachian tube of the child (*Gerlach's Tubentonsille*). Anton* was ablo to trace this tissuo not only as far as the tympanic orifice of tho tube, but into tho tympanic cavity.

Muscles of the Eustachian Tube.—Tho lumon of thc Eustachian tube, tho walls of which are moro or less in contact, is opened principally by the levator and tensor palati muscles, which cxtend from tho Eustachian tube to the soft palato.

The **levator veli palatini** (*petro-salpingo-slaphylinus*, Fig. 46, *l*) arises from the inferior surface of tho petrous bone bordering on tho carotid canal. Its rounded belly runs parallel to tho Eustachian tube, is closely applied to tho membranous portion (Fig. 46, *l*), which forms the floor of thc tube, and is inserted in a radiating manner into tho soft palate below its pharyngeal orifice. None of its fibres arise from tho Eustachian tube, as was formerly believed, but the muselo is attached to it only by a small amount of connec- tive tissuo. Thc action of this musclo is not confincd to thc velum palati alone, but it also raises tho floor of the Eustachian tubo through shortening and swelling of its fibres; this causes thc pharyngeal orifice to become smaller, and the resistance in thc tube to becomo lessened, owing to the widening of its lumen.

The **tensor veli palatini** (*spheno-salpingo-slaphylinus s. circumflexus palati*), called by Tortualf† and v. Tröltseh the abductor or dilator tubæ (Fig. 46, *t, t*) ariscs from tho inferior surfaco of the sphenoid bone and tho inner plate of tho pterygoid proeess; a great number of its fibres also arise from the short, hook-liko, lateral, cartilaginous wall (Fig. 45, *g*), and from the membranous part of the eartilaginous tube. In its downward course its flat belly lies close to the lateral wall of thc mombranous tube, and is rather firmly attached to it. The direction of its fibres forms an acute angle with the cartilaginous portion of tho tube, and its tendon, winding around the hamulus pterygoideus, radiates into tho fibrous prolongation of tho hard palate (Henle). The tendon of the musele is so tightly attached to the hamular process that the effect of its contraction is greater on the Eustachian tube than on the soft palate. By tho contraction of this muscle the earti- laginous hook is slightly unfoldcd, the membranous is lifted from the carti- laginous portion, and the lumen of thc tube is opened. We must still mention another muscle, tho salpingo-pharyngeus, which cxtends from thc palato- pharyngeus to the prominence behind the ostium pharyngeum.

There are three fasciæ conneeted with thc above-mcntioncd muscles; these play an important part in the opening of tho tube, and aro partially inserted into it. They are the following: the salpingo-pharyngeal fascia, which extends from the tube to the hamulus pterygoideus, and scparates thc tensor from the levator muscle; the extcrnal fascia of the tensor; and, lastly, that fascia connected with the ligamentum salpingo-pharyngeum, and lying on the medial surface of the levator muscle.

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* *Zeitschrift für Heilk.*, vol. xxii.
† Politzer, *Geschichte der Ohrenheilkunde*, vol. i., p. 372.

The arteries of the Eustachian tube arise from the ascending pharyngeal, the middle meningeal, and the internal maxillary. The veins communicate with those of the cavum tympani and naso-pharynx, and form a plexus which anastomoses with the cavernous sinus (Zuckerkandl); if this plexus becomes overfilled with blood, it can effect an important change in the lumen of the canal.
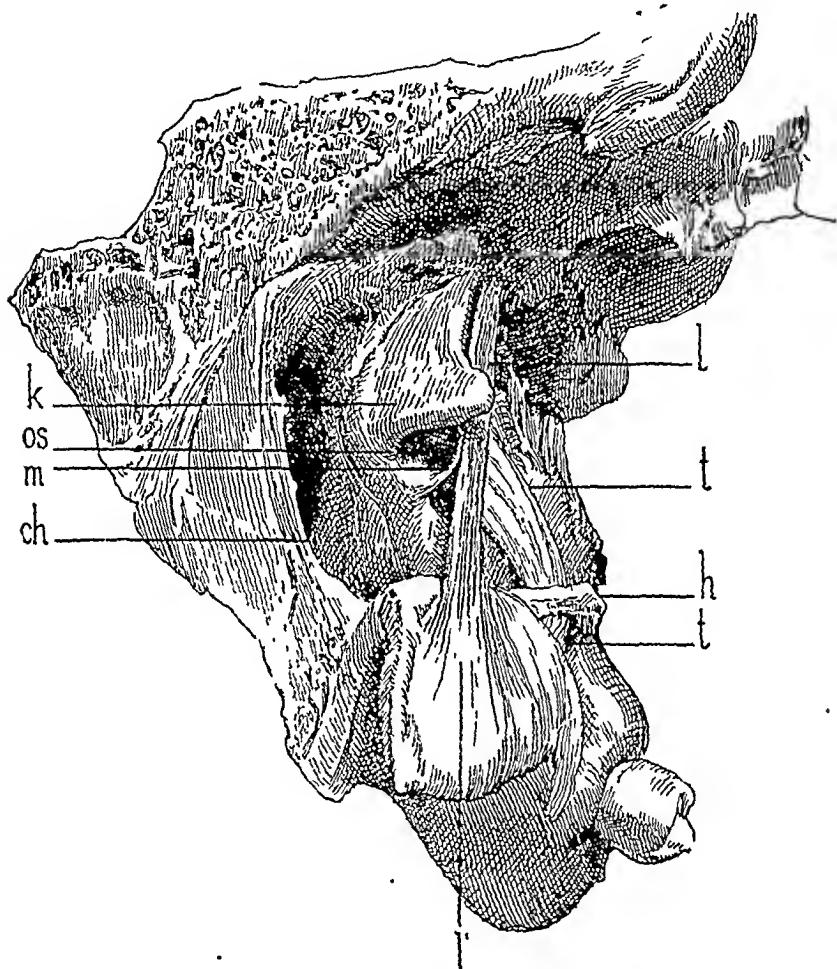
FIG. 46.—EUSTACHIAN TUBE WITH ITS MUSCLES (NATURAL SIZE).

k, Cartilaginous plate of the Eustachian tube; *m,* Lamina membranacea of the Eustachian tube; *os,* Ostium pharyngeum tubæ; *ch,* Choana; *l,* Musculus levator palati mollis; *l',* Radiation of the levator in the velum palati; *h,* Hamulus pterygoideus; *t, t,* Musculus tensor palati mollis winding round the hamulus. From a preparation in the author's collection. (Right side.)

3. The Mastoid Process (processus mastoideus).

The mastoid process forms the posterior part of the middle ear. The first suggestion of such a process in the new-born presents itself as a small tubercle behind the upper part of the annulus tympanicus, which, in the first years of life, enlarges downwards, partly by its own growth, and partly by traction of the muscles.

The mastoid process assumes its adult form only in the third year of life (Zuckerkandl).

The squamo-mastoid suture lies between the anterior surface of the tuberculum mastoideum and the posterior portion of the pars squamosa, and forms the external wall of the tympanic antrum in the new-born. This was already described by Du Verney, and generally disappears during the first years of life, although it may persist in the adult as a jagged, deep furrow on the external surface of the mastoid process.

The tympanic antrum is the only pneumatic space present in the temporal bone in the new-born. It is a long cavity, situated behind the tympanum, and is not only relatively but absolutely larger than in the adult. Its length is 9–10 mm., and its breadth and height 6–7 mm. (Gomperz). According to Zuckerkandl, the development of the cell-spaces in the mastoid proceeds in the

Fig. 47.

following manner: the cellular proliferation begins at the posterior superior periphery of the antrum, it then advances towards the transverse sinus, and finally towards the external lamella.

The fully developed mastoid is divided into two parts: (1) The *horizontal part*, or *antrum tympanicum*, which is a large, extensive, irregular space situated below the tegmen of the mastoid, and is reached through the triangular orifice in the posterior tympanic wall. (2) The *vertical part*, the cells of which communicate with the antrum.

The size and shape of the mastoid present many variations. In some cases it is massively developed, while in others it is reduced to a short solid protuberance. We also find considerable differences in the internal structure of the mastoid process; this, as the older anatomists already knew, is not always composed of pneumatic cell-spaces, but is often formed, either completely or partially, of a spongy, fatty, or compact osseous substance (Zoja).

We therefore differentiate three principal types: the *pneumatic*, the *diploëtic*, and the *mixed* form, a combination of the two. The

pneumatic type is often composed of a large number of irregular
cell-spaces, penetrating the temporal bone in all directions, and
generally covered by a thin, external osseous lamella (Fig. 47).
In other cases the whole process consists of one or two large cavities,
or of numerous small cavities in addition to one or more large ones,
which cause the bony cortex at the apex or on its internal surface
to stand out like vesicles. Large
cavities often communicate with the
antrum only by a narrow canal.

FIG. 48.

The pneumatic cell-spaces often extend
posteriorly to the sutura occipitalis, and
surround the sinus transversus and emis-
sarium Santorini; inferiorly to the incisura
mastoidea, and superiorly and anteriorly
to the linea temporalis and the root of the
zygomatic process, thereby completely
encircling the auditory canal, with the
exception of its anterior inferior wall.
They sometimes reach inwards as far as
the apex of the petrous bone. The pneu-
matic cells often completely surround the labyrinth and directly adjoin the
bulbus venæ jugularis, the osseous portion of the Eustachian tube, and the
posterior part of the carotid canal.

The diploëtic mastoid process shows an entirely different
appearance on section (Fig. 48). Such a type consists, from its
apex (Fig. 48, *c*) to its superior border (*b*), of small-celled diploë
and fatty osseous tissue, and only occasionally presents air-cells
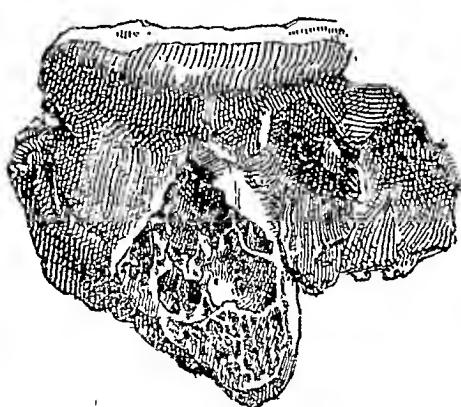
FIG. 49.
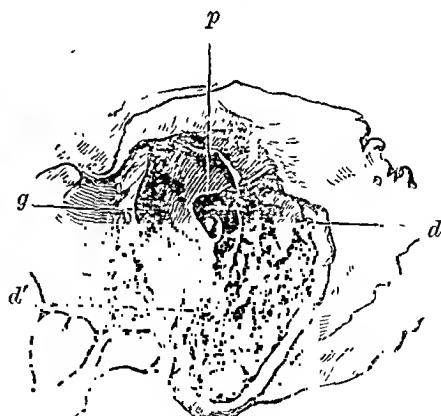
FIG. 50.

in the vicinity of a small mastoid antrum. The sclerotic mastoid
process is seldom entirely compact, but contains either very dense
diploëtic tissue or large single cavities. The diploëtic and
sclerotic processes are generally smaller than the pneumatic.

The third type is partly pneumatic and partly diploëtic. One
finds, however, innumerable varieties, the most frequent of

which are those in which the inferior part is diploëtic, the superior, pneumatic (Fig. 49), or the inferior and posterior part contain (d, d′) diploë (Fig. 50), while the anterior superior (g, p) has pneumatic cells.

The pneumatic cells of the mastoid process are lined with a delicate membrane which contains no glands, and which is a continuation of the mucous membrane of the tympanic cavity; it is closely united to the periosteum, and has a layer of non-ciliated squamous epithelium. One often finds membranes of connective tissue and branch-like bands in the antrum, upon which the pedunculated bodies lie, which were described on p. 36 (Fig. 42).

The cells of the mastoid are bounded anteriorly by the posterior wall of the osseous meatus (Figs. 51 and 52), and partly by the posterior end of the petrous bone and the tympanic cavity. The external wall (planum mastoideum) is formed by the convex
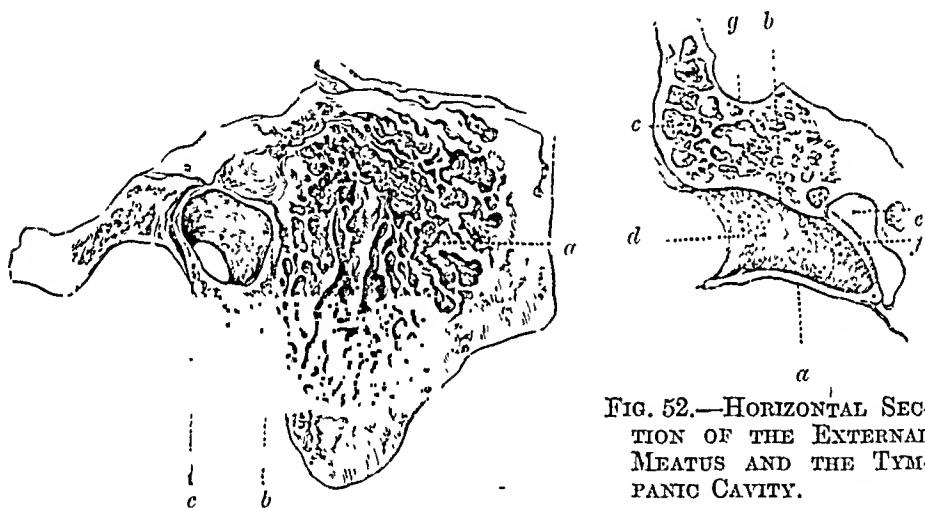
FIG. 51.—VERTICAL (SAGITTAL) SECTION OF THE MASTOID PROCESS AND THE OSSEOUS MEATUS.

a, Mastoid cells; b, Posterior wall of the osseous meatus; c, Anterior wall of the osseous meatus.

FIG. 52.—HORIZONTAL SECTION OF THE EXTERNAL MEATUS AND THE TYMPANIC CAVITY.

a, Anterior wall of the meatus; b, Posterior; c, Cells of the mastoid process; d, Meatus; e, Membrana tympani; f, Tympanic cavity; g, Fossa sigmoidea. (Right ear.)

osseous plate which can be felt behind the auricle, and which varies greatly in extent and thickness (4–10 mm.). Where the planum mastoideum passes into the posterior wall of the meatus, an inconstant pointed eminence is found on the posterior superior periphery of the external auditory orifice, which varies in size, and is called the spina supra meatum. According to Mancioli, the distance of the spina supra meatum from the apex varies between 17 and 34 mm.

The mastoid process articulates posteriorly with the occipital bone, in which cells are occasionally found communicating with those of the mastoid (pneumatic occipital bones, Hyrtl). The

superior wall of the mastoid process directed towards the cranial cavity is called the *tegmen mastoideum*, and is formed partly by the posterior continuation of the *tegmen tympani* and the inner lamella of the horizontal part of the squamous portion of the temporal bone.

The inner boundary of the mastoid process is divided into two parts, an inferior and a superior. The inferior is that part of the mastoid lying on the internal side of its conical portion, and is grooved, in a sagittal direction, by the *incisura mastoidea;* this is of variable depth, and serves for the insertion of the digastric muscle. The osseous wall is frequently as thin as paper at this place, and sometimes forms the medial boundary of one large pneumatic cell which takes in the entire apex of the mastoid process (terminal cell). The superior is traversed by the winding course of the lateral sinus, which originates at the torcular
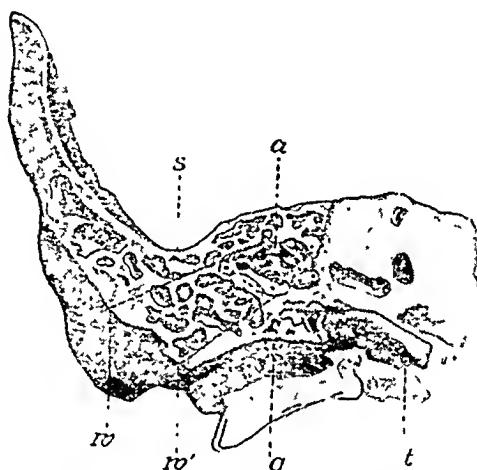
FIG. 53.—HORIZONTAL SECTION THROUGH A PNEUMATIC MASTOID PROCESS.
g, Posterior wall of the meatus; *t*, Cavum tympani; *a*, Mastoid antrum; *s*, Sigmoid sinus; *w*, *w'*, Seat of operation on the external cortex of the mastoid process.

Herophili, passes over the inner surface of the mastoid process, and arriving at the foramen jugulare, rises with an abrupt curve towards the inferior wall of the pars petrosa, where it empties into the sinus of the internal jugular vein (jugular bulb). Suppurative inflammations of the mastoid which extend to this wall may, therefore, bring about a fatal sinus phlebitis.

Anomalies in the position of the sigmoid sinus to the mastoid process and posterior wall of the meatus are of great practical importance. Bezold and Hartmann have called attention to the fact that when the sigmoid sinus lies far anteriorly and externally, there is great possibility of injuring it when opening up the mastoid process. The author found in more than 500 temporal bones that the sinus is less apt to be injured when the mastoid process is strongly developed and entirely filled with pneumatic spaces.

In these cases (Fig. 53), there was a broad space between the *sinus transversus (sigmoideus)* and the posterior wall of the meatus (*g*) which enables one to perform the operation for opening up the middle ear without danger of wounding the sinus.

According to the observations of the author, the relations are less favourable in the majority of cases in which the mastoid process is diploëtic or compact. In such cases, the space between the sinus and the posterior wall of the meatus is often much smaller (Fig. 54), and is occasionally shifted so far anteriorly and externally that only a small connecting bridge (Fig. 55) exists between it and the posterior wall of the meatus; it is obvious, therefore, that in operations on such mastoids the possibility of exposing the sinus is almost unavoidable.
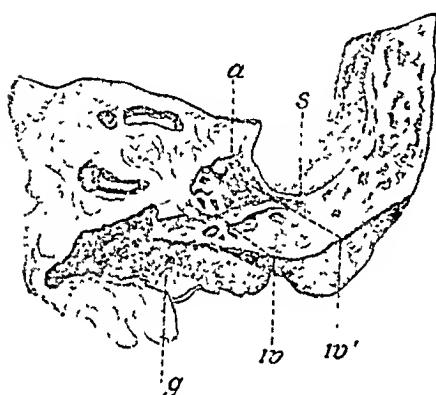
FIG. 54. — HORIZONTAL SECTION THROUGH A MASTOID PROCESS, PARTLY DIPLOËTIC, PARTLY PNEUMATIC.

g, Posterior wall of meatus; *a*, Mastoid antrum; *s*, Sigmoid sinus; *w, w'*, Basis for operation.
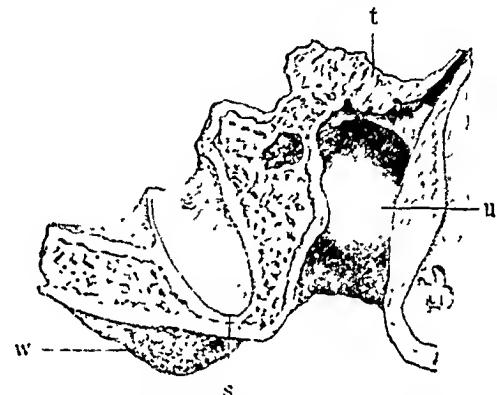
FIG. 55. — HORIZONTAL SECTION THROUGH A COMPACT MASTOID PROCESS, CONTAINING A SMALL AMOUNT OF DIPLOË.

t, Cavum tympani; *u*, Inferior wall of meatus; *s*, Sigmoid sinus; *w*, Posterior boundary of basis for operation.

The cells of the mastoid are supplied by branches of the middle meningeal and stylo-mastoid arteries, and its external surface by the posterior auricular. The external veins are connected, partly with the veins of the neck which empty into the jugular, and partly with the emissaria Santorini which come from the cranial cavity through the pars mastoidea. The veins of the antrum and mastoid cells partly anastomose with those of the cavum tympani and cortical layer, and partly empty into the emissaria Santorini; others communicate with the sigmoid sinus through small bony canals in the inner wall of the mastoid process. Besides these, there is a vascular canal which passes from the interior of the mastoid process beneath the superior semicircular canal through the fossa subarcuata into the cranial cavity. The veins of the diploëtic spaces of the mastoid are in direct communication with the other veins of the temporal bone, and with the venous sinuses of the cranial cavity. The nerves of the antrum and mastoid cells arise from the tympanic plexus, and those of the external surface, from the auricularis magnus.

The Topography of the Sound-conducting Apparatus.

1. **The Auricle.**—Its topography is best studied by means of frozen horizontal and vertical sections, or on specimens hardened in alcohol. In such specimens the greater portion of the cartilage will be seen to stand away from the lateral surface of the skull; still, that portion which surrounds the external orifice is, to a varying extent, in contact with the squamous and mastoid portions of the temporal bone. The middle segment of the concha behind the external auditory orifice is attached, to the extent of $1\frac{1}{2}$–2 cm., to the mastoid process by means of flexible connective tissue. This fact is of importance in so far as this segment of the auricle covers that portion of the mastoid where the operative opening of the same is indicated, and by which procedure the auricle is partially detached from the mastoid process. That portion of the auricle which forms the tragus is contiguous, on its innner side, with the cartilaginous meatus and with the external surface of the maxillary joint.

2. **The Cartilaginous Meatus.**—This part of the auditory canal is partially covered by the walls of the osseous meatus. The superior wall of the osseous meatus roofs over the membranous portion of the auditory canal as far as the external auditory orifice, and in a similar manner the external portion of the posterior wall formed by the mastoid process extends beyond the cartilaginous meatus. One can, therefore, feel the superior and posterior walls of the osseous meatus directly behind the external auditory orifice by inserting the finger into the cartilaginous canal. Only the external portion of the lower and longest wall of the cartilaginous meatus is freely palpable, the inner portion being covered by the parotid gland. The internal portion of the anterior cartilaginous wall is contiguous with the posterior surface of the capsule of the maxillary joint, the movements of which are communicated to this wall.

3. **The Osseous Meatus.**—This portion of the auditory canal is bounded above by the middle cranial fossa, behind by the cells of the mastoid process, and in front by the maxillary joint; the cavity of this joint lies higher than the osseous meatus and extends further externally than its anterior wall.

4. **The Membrana Tympani.**—The knowledge of the topographical relation of this membrane to the internal tympanic wall is of great practical importance. The importance of this relation becomes evident in judging pathological changes in the membrana tympani, and also in performing operations upon it and in the tympanic cavity. We divide the external surface of the membrana tympani into four segments in order to clearly understand its relation to the internal tympanic wall (Fig. 56). This is accomplished by prolonging a line downwards from the handle of the malleus, and intersecting it by a horizontal line tangent to its lower extremity. The points of projection, as given by Zuckerkandl,* of the inner tympanic wall to the drum membrane apply perfectly to anatomical specimens, but are considerably modified in practice on account of the inclination of the membrane to the horizontal plane.† In the normal position of the head, in which otological examinations are made, we find that:

1. The *anterior superior quadrant* of the membrana tympani (*a*) corresponds to the anterior superior portion of the inner tympanic wall which

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* *Realencyclopïdie der med. Wissenschaften.* Wien, 1886. Article *Gehörorgan.*

† This difference in projection between anatomical aural preparations and the ears of the living is also due to the oblique position of the temporal bone when *in situ,* and also to the position in which Zuckerkandl held the specimen while making his projections.—TRANSLATOR.

borders on the tympanic orifice of the Eustachian tube; a part of the semi-canal for the tensor tympani muscle is seldom seen in this quadrant.

2. The *anterior inferior quadrant* (*b*) corresponds to the anterior inferior part of the inner tympanic wall which borders on the ostium tube, and also presents a portion of the jagged anterior and inferior walls.

3. The *posterior superior quadrant* (*c*) corresponds to the posterior superior part of the inner tympanic wall which presents the incudo-stapedial joint above, behind this the eminentia stapedia and the tendon of the stapedius, and below this the superior part of the recess or niche of the round window (*e*).

4. The *posterior inferior quadrant* (*d*) corresponds to the posterior inferior part of the inner tympanic wall which presents the inferior part of the recess of the round window above (*e*), and below a portion of the jagged inferior tympanic wall.

The above described projection of the inner tympanic wall to the membrana tympani shows many variations which must be borne in mind, both in ocular inspection and in operative procedures. The long process of the incus, and its articulation with the stapes, often lie so low that the greater part of the recess of the fenestra ovalis, the posterior crus of the stapes, and the stapedius tendon are clearly visible. One finds, in other cases, the articulation of the incus and stapes so high that it is completely hidden by the annulus tympanicus, and cannot be seen even if the membrana tympani is completely destroyed. In like manner, the recess of the round window may often lie so low that it appears to be situated in the posterior inferior quadrant of the membrane.

FIG. 56.—PROJECTION OF THE INNER WALL OF THE TYMPANIC CAVITY WITH RESPECT TO THE MEMBRANA TYMPANI.

a, Ant. sup. quadrant of membrana tympani; *b*, Ant. inf. quadrant of membrana tympani; *c*, Post. sup. quadrant of membrana tympani; *d*, Post. inf. quadrant of membrana tympani; *e*, Niche or recess of the fenestra rotunda.

The width of the tympanic cavity varies considerably in its different parts which is due to the normal, funnel-shaped retraction of the membrane, and to the bulging of the inner tympanic wall. We obtain the clearest conception of the topography of the tympanic cavity from frontal and horizontal sections (Figs. 57 and 58), and from corrosion specimens. The distance of the umbo from the promontory is, on the average, 2 mm. The most prominent part of the promontory corresponds to a point $1-1\frac{1}{2}$ mm. below the umbo; this point is about $2\frac{1}{2}$ mm. distant from the membrane. The distance of the posterior inferior quadrant of the membrane from the inner tympanic wall varies, according to Bezold, from 5–7 mm.; the anterior superior quadrant, according to the measurements of the author, from 5–6 mm.; and the anterior inferior quadrant from 4–5 mm. The distances are less in the new-born and during the first years of life. The width of the tympanum at the anterior part of the attic varies from 3·5–4 mm., while on the floor, anteriorly, it is 3–3·5 mm.; at the posterior part of the attic it is 5–6 mm., while on the floor, posteriorly, it is 5–5·5 mm. The height of the tympanum varies from 10–12 mm.; the height of the anterior wall to the ostium tympanicum tubæ is 3·5–4 mm.; that of the posterior wall 8–9 mm. The distance from the ostium tympanicum tubæ to the posterior wall is 13 mm. (Bezold). According to Schöneman,* a marked rotation of the petrous portion of the temporal bone on its axis causes the posterior cranial fossa to lie deeper.

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* *Schläfebein und Schädelbasis.* Basel, 1906.

5. **The Position of the Ossicles.**—Their position and relation to the walls of the tympanic cavity are shown in Fig. 57. The head of the malleus and body of the incus lie in the superior tympanic cavity in a small depression
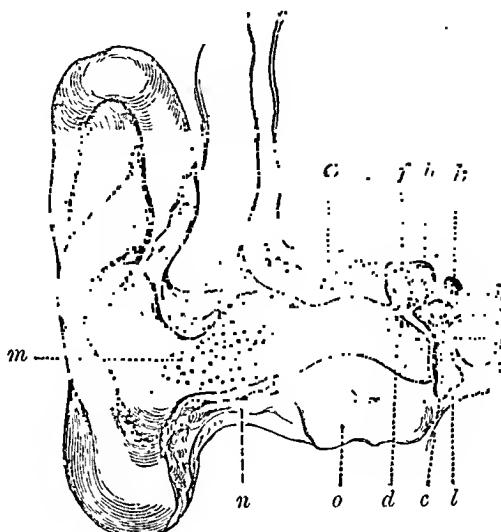
FIG. 57.—FRONTAL SECTION OF THE EXTERNAL MEATUS, MEMBRANA TYMPANI, AND TYMPANIC CAVITY.

a, Cellular spaces in the superior wall of the meatus connected with the middle ear; *b,* Roof of the tympanic cavity; *c,* Inferior wall; *d,* Tympanic cavity; *e,* Membrana tympani; *f,* Head of the malleus; *g,* Handle of the malleus; *h,* Incus; *i,* Stapes; *k,* Canalis facialis; *l,* Fossa jugularis; *m,* Glandular orifices in the external meatus. (Right ear.)
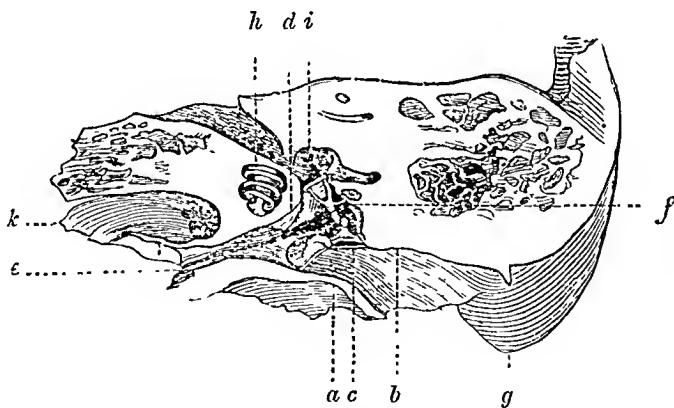
FIG. 58.—HORIZONTAL SECTION OF THE EAR.

a, Anterior wall of the osseous meatus; *b,* Its posterior wall; *c,* Section of the membrana tympani, of the handle of the malleus, and of the posterior pouch; *d,* Promontory; *e,* Ostium tympanicum tubæ; *f,* Stapes in connection with the inferior extremity of the long process of the incus and of the tendon of the stapedius; *g,* Mastoid process; *h,* Cochlea; *i,* Vestibule; *k,* Carotid canal.

on the outer wall (*logette des osselets,* Gellé). Their proximity to the superior and external tympanic walls facilitates the formation of adhesions between the malleo-incudal body and the above-mentioned walls The stapes is placed

nearly at right angles to the long axis of the malleus and incus, and lies with
its crura in a recess on the inner tympanic wall; this leads to the fenestra
ovalis, and may be compared to a short duct—*fossula fenestræ vestibuli,
pelvis ovalis* (Fig. 59). It not infrequently happens that both crura become
attached to the inferior wall of the above-mentioned recess, either directly or .
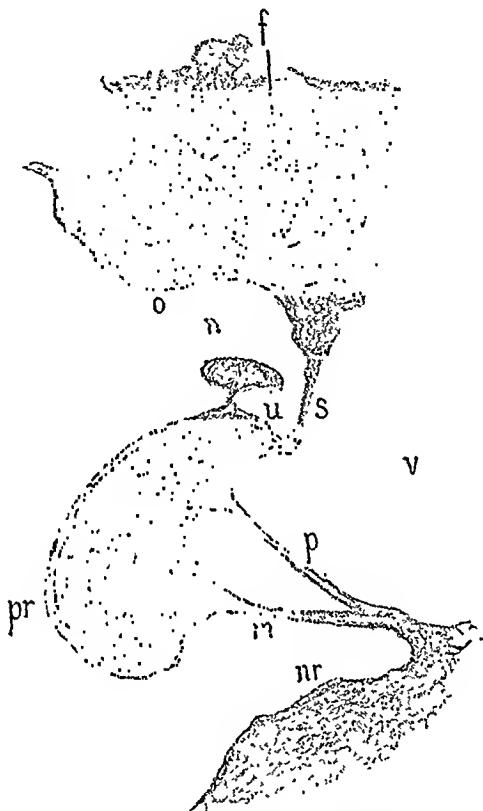
FIG. 59.—FRONTAL SECTION OF THE INNER TYMPANIC WALL THROUGH THE
TWO LABYRINTHINE FENESTRÆ.

s, Basis stapedis; *n,* Niche or recess of the fenestra ovalis with a portion of the crus
of the stapes, which has been divided obliquely; *o,* Upper, *u,* lower wall of the
niche; *pr,* Section of the promontory with its mucous covering; *m,* Membrana
fenestræ tympani secundaria; *nr,* Niche of the fenestra rotunda; *p,* Lamina
spiralis secundaria; *f,* Section of the facial nerve; *v,* Vestibule. From a prepara-
tion in the author's collection.

by inconstant folds of mucous membrane. Inflammations of this region,
therefore, facilitate the ankylosis of the crura with the inferior wall of this
recess.

6. **The Mastoid Process.**—Its topography has already been given on
p. 43; the position of the Eustachian tube, especially its pharyngeal orifice,
which is important in catheterization, will be described in the chapter on this
subject.

The Physiology of the Sound-conducting Apparatus.

A. The Auricle.

IT was formerly believed that the different depressions on the anterior surface of the auricle played an important part in reflecting the waves of sound. We now know that they possess a very small physiological function, inasmuch as individuals deprived of their auricles through frost-bite or mechanical injury sustain only a slight loss of hearing.

There can be no doubt, however, that the auricle plays an essential part in bringing about a more acute hearing, although not to such an extent in man as in some animals. Of all the depressions on the anterior surface of the auricle, it is principally the concha which collects a portion of the waves of sound and reflects them into the meatus. Schneider has proved that a decrease in the power of hearing takes place if this depression is filled with wax. In reference to the above, the author experimented on individuals who were hard of hearing, because in such persons the hearing distance for continuous sound appears to be more sharply defined than in individuals of normal hearing. The experiments were carried out as follows: The head of the patient having been placed in a fixed position, and the hearing distance having been ascertained by a metronome, the instrument was brought within the boundary of the hearing distance, whereupon its tick was immediately lost to the patient when the concha was covered with a stiff piece of paper. The external auditory orifice must not be closed during the above experiment. No alteration in the hearing distance took place if the other depressions were covered.

The size of the auricle and the angle it forms with the side of the head also have an influence upon the reflection of sound into the meatus (Buchanan). This will be seen from the fact that persons of normal hearing, as well as those hard of hearing, hear more distinctly if the auricle is bent forwards, or augmented by the hollow of the hand.* Although no hardness of hearing will result from the loss of the auricle, nevertheless sound will not be perceived as distinctly and fully as if it were present.

According to the investigations of the author, the tragus must be considered of great importance in the reflection of the waves of sound. It appears as a nipple-like projection directed backwards in front of and slightly overlapping the external orifice of the ear, whereby a considerable space is formed opposite the concha. The waves of sound reflected by the auricle (concha) are collected in this space, and then thrown into the external orifice of the ear.

We can convince ourselves of the importance of this space if we modify the above-described experiment by filling this recess with cotton steeped in liquid vaseline. By this means, the sound of the metronome will either be heard less intense or not at all. If, on the other hand, the surface of the tragus is enlarged backwards, by applying a small firm plate the perception for sound will be markedly increased.

It is therefore beyond doubt that the auricle plays an important part in reflecting the waves of sound into the external auditory canal, and thereby considerably intensifying our sound perception.

The muscles inserted into the auricle have, in man, only a slight influence upon its position during the act of hearing. On the whole, voluntary movements of the auricle are rare. The author has rather frequently observed,

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* This was already practised by the Emperor Hadrian. Politzer, *Geschichte der Ohrenheilkunde*, vol. i., p. 28.

however, reflex motions of the auricle while testing the hearing or syringing the ear, of which the patient knew nothing; these motions were visible in different portions, and at times over the whole auricle.

B. The Conduction of Sound in the External Auditory Canal.

Most of the waves of sound passing through the external auditory canal strike the drum membrane directly. It must be borne in mind, however, that, owing to the numerous curvatures in the meatus, they are repeatedly reflected and slightly weakened.

The width of the meatus has only a slight influence on the intensity of sound perception. We can convince ourselves of this fact if we first take the hearing distance for the ticking watch, and then insert a wax ball into the middle of the auditory canal, so as to reduce its lumen to a small fissure. From this experiment it will be seen that the hearing distance is only slightly altered and the sound of the tick hardly diminished.

C. The Propagation of Sound through the Membrana Tympani and the Ossicles.

The membrana tympani, like artificial membranes which have a fixed tension, possesses the property of transmitting tones of the most varied vibrations; these tones are uniformly perceived, not only if they strike the membrane in succession, but also simultaneously. It must not be looked upon, however, as an elastic membrane, but is, from the anatomical arrangement of its fibres, a stiff, slightly elastic structure. This property is of importance, as it prevents over-vibrations which would impair the distinctness of perception. According to experimental research, the membrana tympani possesses its own tone (e^{iv}); it can vibrate independently, but only to a slight extent, on account of the stiffness of its fibres.

The normal, funnel-shaped retraction of the membrane, produced by the tension of the manubrium, exercises an important influence upon its vibratory function. Helmholtz[*] has proved by experiment that the power of resonance of curved membranes is far greater than that of flat ones. He conducted the tones of a stretched string by means of a wooden pin to a curved membrane stretched across a glass cylinder, and found that the resonance of this membrane extended over a large part of the scale, and that in deep and high tones, which were produced by lengthening or shortening the string, a curved membrane was thrown into more intense vibrations than a flat one. Mach and Kessel[†] found that the excursions of the posterior segment of the membrane were considerably greater than its other parts, and also that the vibrations of the membrane, during

[*] *Die Mechanik der Gehörknöchelchen und des Trommelfells. Pflüger's Arch.*, vol. i.

[†] *Beiträge zur Topographie und Mechanik des Mittelohrs. Wiener Acad. Sitzungsberichte*, April, 1874.

the phase of condensation, travel in a circular manner from the periphery to the centre, while in the phase of rarefaction they travel from the umbo to the periphery.

While the membrane is drawn inwards in a funnel-shaped manner, it is, at the same time, bulged towards the external auditory canal from the umbo to the periphery. The radiating fibres extending from the periphery to the handle of the malleus represent a system of stretched strings,* to which the manubrium is attached as a movable bridge. According to Helmholtz, the radiating fibres, on account of their external bow-shaped curvature, offer a favourable point of contact to the waves of sound. The investigations of the author † regarding this showed, however, that the strength and transmission of sound were just as intense, whether the membrane was concave or convex towards the direction of the sound. Helmholtz has further demonstrated that a slight motion of the extremity of the manubrium takes place in proportion to a relatively great excursion of the membrane, and *vice versa*. The inclination of the drum membrane to the axis of the meatus does not weaken to any important degree the force of the waves of sound which strike it.

Transmission of Sound from the Membrana Tympani to the Labyrinth.—The vibrations of the membrana tympani are partly transmitted to the labyrinth through the ossicles by means of the foot-plate of the stapes, and partly through the air of the tympanic cavity to the membrane of the fenestra rotunda. While Pascal, Sapolini and Secchi, and at a more recent date Kleinschmidt and Zimmermann, claimed that the waves of sound were conducted principally by the column of air from the drum to the round window, we must now consider, on the bases of physiological experiments and pathological findings, that the ossicular chain is the principal means by which sound reaches the labyrinth. The ossicular chain is looked upon by these authors more as an apparatus to tone down the force of the waves of sound—an apparatus of accommodation. This theory, which, according to the author's experiments, was shown to be unsound, was regarded in a similar light by Eschweiler‡ and Nuvoli,§ and also by Mader‖ and Exner.¶ The latter authors condemned the above theory on the interesting experiments based on the microphonic observation of the vibrating ossicles.

The ossicles form a system of sensitive levers, by which the vibrations of the membrana tympani are transmitted to the labyrinth.

By means of a series of experiments conducted by the author in the year 1861 (*A. f. O.*, vol. i.), it was shown that the ossicles vibrated as whole bodies with extensive amplitudes due to the waves of sound acting upon the drum membrane.

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* This statement was first made by the author and corroborated by Fick.

† *Zur physiolog. Acustik und deren Anwendung auf die Pathologie des Gehörorgans* (*A. f. O.*, vol. vi.).

‡ *Archiv für Ohren.*, vol. lv.

§ *Archivo italiano di Otologia*, vols. x. and xiii., and *Phisiologia del udito* (Roma, 1907).

‖ *Sitzungsbericht d. Akad. d. Wissenschaft in Vienna*, vol. cix.

¶ *Wien. klin. Woch.*, 1900.

The proportional amount of vibration of the ossicles depends principally on the mechanism of their joints. In 1862 the author discovered (*Wiener med. Wochenschr.*, Nos. 13 and 14) that when the air was condensed in the tympanic cavity, a considerable outward excursion of the membrana tympani with the handle of the malleus took place, and a distinct motion of the articular surfaces of the malleus and incus was visible, while the excursions of the long process of the incus were very trifling. In this experiment, we see the mechanism of the malleo-incudal articulation, which was later described by Helmholtz. He compared this articulation to the mechanism of the catch contrivance in a watch-key. With the inward excursion of the malleus, its cog catches that on the body of the incus, whereby the latter must follow the motion of the former; with the outward motion of the hammer, however, its cog unhooks itself from that of the incus, causing the malleus to move strongly outwards, while the incus and stapes do so only to a slight degree.

The action of the sound-conducting apparatus is compared by Helmholtz to that of an unequal lever, which executes great excursions at one end and small ones at the other. If, according to the foregoing, the vibrations are lessened as the waves of sound progress from the membrane through the ossicles, their intensity is in no way diminished, if one understands the principle of active force.

Owing to the construction of the articulation of the malleus and incus already described, the organ of hearing is protected from violent concussions acting upon the membrane. As a result of these concussions on the drum, which are brought about by the sudden condensation of air in the external auditory canal, these violent shocks, which would otherwise reach the labyrinth, are broken by the radiating fibres which are bulged towards the meatus, and which extend between the annulus tympanicus and the handle of the malleus; this bow formation can shorten and become tense by the force exerted upon it before the hammer is driven with great violence against the incus.

In like manner, the labyrinth is protected against excessive variations of pressure brought about by a violent entrance of air into the tympanum through the Eustachian tube, inasmuch as the membrana tympani, with the handle of the malleus, is forced outwards to a considerable extent, while the incus and stapes follow this motion only to a slight degree.

The check to the over-vibration of the ossicles is brought about partly by their articular ligaments, and partly by the ligaments and folds of mucous membrane extending from the tympanic wall to the ossicles. These checks are of the greatest importance in governing the uniform reception and conduction of the various waves of sound (Riemann, Helmholtz). They give the ossicular

chain a sufficient amount of stability by which that necessary relation between the tension of the membrana tympani and that of the ossicles is maintained.

Application of the Foregoing to the Pathology of the Ear.

The disproportion between the tension of the membrana tympani and that of the ossicles, induced by pathological processes, must lead to an impairment in the propagation of sound. An increased tension of the membrana tympani will also produce a proportionate tension in the ossicles; this tension of the membrane is not infrequently brought about by the rarefaction of air in the tympanum, due to closure of the Eustachian tube, and by the action of the atmospheric pressure upon its external surface. The result of this is an abnormal obstruction to the propagation of the sound waves, and therefore a hindrance to the conduction of sound to the labyrinth. Furthermore, we meet with cases where the membrana tympani loses its normal tension by becoming thinned and atrophied, either from a long-continued, one-sided pressure or through extensive cicatricial formation. In such cases, the disproportion between the tension of the membrane and the ossicles also leads to a disturbance of function.

The author has applied the principle of Lissajous, as used by Buck, in a number of experiments. The results thus obtained are of importance in explaining the disturbances of hearing which are observed as sequelæ of pathological obstacles to the conduction of sound. As a fixed point on the ossicles appears under the microscope as a line during their vibration, the intensity of these vibrations may be measured by the alteration in the length of this line. The results of these experiments, published by the author in the year 1871 (*A. f. O.*, vol. vi.), are as follows:

1. If the tones of a harmonium were conducted by means of a tube to the membrana tympani of an anatomical specimen, it was found that with tones of equal intensity the vibrations of the ossicles were less with deep tones than with those of the middle range, while with very high tones the intensity of the vibrations markedly decreased.

2. If words were spoken into the meatus through a hearing-trumpet, the ossicles exhibited as many oscillations as there were syllables in the word. The greatest oscillation coincided with the vowel of the syllable.

3. If different parts of the membrane were weighted with a small ball of wax or a little rod, the intensity of the vibrations of the ossicles decreased only to a slight degree; but if the malleus, incus, or stapes was weighted, producing, in other words, a similar obstruction to sound as we find in diseases of the middle ear associated with exudations and adhesions, the vibration was considerably diminished.

4. If deep or high tones acted upon the membrana tympani while the ossicles were weighted as above, a comparatively greater vibration was observed with high than with deep tones. The vibrations were also notably less during speech than during the production of musical tones.*

These results agree with the disturbance of hearing observed in patients. Changes on the membrana tympani, such as cicatrices, chalk deposits, and perforations, impair the power of hearing less than pathological changes (adhesions, ankylosis) on the ossicles, which diminish their vibration. It is

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* Professor de Rossi writes, in his *Prolusione fatta al corso di otoiatria per l' anno scolastico*, 1898-99, p. 7: ' *Parecchi anni or sono, udii dalla bocca stessa dell' illustre Graham Bell, l' inventore del telefono, che le sue primi indagini gli furono suggerite dai geniali esperimenti del otoiatra Viennese Adam Politzer, sulle excursioni della catena timpanica.*' This statement is also confirmed by Professor Blake, of Boston, U.S.A.

also seen that in such cases high notes are generally heard better than low ones, and that the perception of speech is more altered than that of musical tones.

5. If the membrane was artificially destroyed, the vibrations of the malleus became less; but if an artificial membrane was inserted and brought into contact with the handle of the malleus, its vibrations again increased.

6. The clicking sounds in the ear during intense concussions, as observed by Helmholtz, are not caused, in the opinion of the author, by the striking together of the cogs of the malleo-incudal articulation. His experiments have shown that this is brought about by the whizzing of the membranes and ligaments of the ossicles, inasmuch as these clicking sounds could be produced in the ears of a cadaver by the tones of an organ-pipe, in spite of the fact that the malleo-incudal articulation had been artificially ankylosed.

D. The Physiology of the Eustachian Tube.

It is a known fact that air is forced into the tympanic cavity by means of a powerful act of expiration when the mouth and nose are closed, and that the membrana tympani is slightly bulged outwards by this procedure (*Valsalva's experiment*). As a result of this, a sensation of fulness and ringing in the ear, and a slight degree of deafness, especially for deep tones, are brought about.

A similar sensation is perceived if an act of swallowing is performed with the mouth and nose closed (*Toynbee's experiment*). In such cases, as the author has shown experimentally, the air in the tympanic cavity becomes somewhat condensed only in the beginning of the experiment, while at the end it becomes greatly rarefied.

If the nostrils are again opened after the act of swallowing, the feeling of tension in the ear nevertheless remains, and only disappears when the act of swallowing is repeated with the nostrils open.

The explanation of this is as follows: During the act of swallowing, the Eustachian tube is opened by the action of its muscles, and the rarefaction of air, arising in the pharynx, extends to the tympanic cavity. Immediately after the act of swallowing, however, the walls of the tube again lie close together, and the air in the tympanic cavity remains rarefied, while the atmospheric pressure in the pharynx again returns to its former state. As there is now a difference in the pressure of air in the tympanic cavity and in the pharynx, the membranous part of the tube is pressed closer to the cartilaginous portion by the atmospheric pressure, so that the closure of the tube is more complete than under ordinary circumstances. If another act of swallowing is performed, the tube will again become patulous, and the pressure of air between the tympanic cavity and the pharynx is equalized.

The author obtained these results from a number of experiments undertaken by him in the year 1860 in Professor C. Ludwig's laboratory. He used a small glass tube, 2–3 mm. wide, and provided with a drop of coloured fluid.

This was fitted into a rubber stopper which was hermetically sealed into the external auditory canal (*ear manometer*, Fig. 60). The fluid was seen to rise in the manometer during Valsalva's experiment. If an act of swallowing was performed with the mouth and nose closed, a slight rise (*positive fluctuation*) of the fluid was observed during the first stage of this act; during the second stage, however, a considerable fall (*negative fluctuation*) of the fluid was observed as the air in the tympanum was rarefied and the membrana tympani pressed inwards. After the act of swallowing, the fluid remained in the place where it had fallen, and returned to its former position only when the Eustachian tube was reopened by another act of swallowing with open nostrils. In some cases, even with quiet respiration, slight fluctuations of the fluid in the manometer were observed, which corresponded with the respiratory movements. These fluctuations were greater the more quickly the air was allowed to pass through the nose, and when a greater obstacle was produced to the passage of air by closure of one nostril.

Fig. 60.—Ear Manometer.

The proof that the Eustachian tube is opened during an act of swallowing can also be demonstrated by another simple experiment performed by the author in 1869. If a vibrating tuning-fork c^1 (256 v) is held before the nostrils, a uniform, weak sound is heard; during an act of swallowing, however, the tone of the tuning-fork is perceived greatly increased, as its vibrations freely enter the tympanic cavity through the open Eustachian tube.

Attention has already been called to the fact, in the chapter on anatomy, that the mucous membrane surfaces in the middle portion of the Eustachian tube lie in contact. This portion of the cartilaginous tube, as the author has observed in a number of specimens, is sometimes long and sometimes very short, and therefore explains the varying degree of resistance in normal individuals to the passage of air from the pharynx to the tympanic cavity.

The question whether we are able to hear through the Eustachian tube, and thereby understand speech when the conduction of sound is excluded from the external meatus and the membrana tympani, is positively shown by the following experiment: The nozzle of a speaking-tube 1 metre in length is introduced into the nostril of an individual with normal hearing, and the nostrils firmly closed around it by a second person; the meatuses are then firmly closed by the moistened fingers of the individual experimented upon, so that he cannot understand speech at a distance of 1 metre. If now spoken to, however, through the hearing-trumpet he will immediately understand speech. Some persons during this experiment understand whispered, while others only loud speech; this is explained by the fact that the walls of the tube lie more closely in contact in some individuals than in others.

These experiments give the following results:

1. The Eustachian tube is not constantly open; its permeability varies individually, inasmuch as in a number of cases a current of air extends from the pharynx to the tympanic cavity even during quiet respiration; in other cases, however, an act of swallowing or a powerful expiration with open or closed nostrils is necessary to make the tube permeable.*

2. The Eustachian tube is opened during the act of swallowing, chiefly by the action of its muscles, especially by the abductor

* Confirmed by Mach and Kessel: *Die Function der Trommelhöhle und der Tuba Eustachii. Wien. Acad. Sitzungsberichte*, 1872.
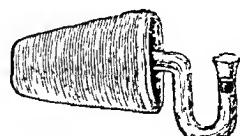
tubæ,* as is shown by the experiments of v. Tröltsch, Toynbee, and the author.†

3. A difference of pressure is more easily equalized when the interchange of air takes place from the tympanum to the pharynx, than from the latter to the former.

Application of the Foregoing to the Pathology of the Ear.

From the above-mentioned physiological facts, we gather the following:

1. The permeability of the Eustachian tube is of great importance for the function of hearing. If the tube becomes impermeable through swelling of its mucous membrane, or through accumulation of secretion, congestion and transudation develop in the middle ear as a result of a rarefaction, due to the shutting off of the air. As the atmospheric pressure predominates, the membrana tympani and the ossicular chain are tensely forced inwards, whereby their power of vibration is diminished.

2. Through the opening of the Eustachian tube which takes place during the act of swallowing, the resistance which opposes the current of air from the pharynx to the tympanic cavity is considerably lessened. Where it is necessary in diseases of the middle ear to render the tube permeable, and allow a strong current of air to enter the tympanic cavity, the effect will be materially increased if an act of swallowing is performed during the inflation.

E. Influence of the Variations of Air-pressure in the Tympanic Cavity on the Tension of the Contents of the Labyrinth.

The sensation of fulness or tension in the ear, which is accompanied by a ringing and slight degree of deafness, and which arises from condensation and rarefaction of air in the tympanic cavity, has, since the time of J. Müller, been attributed to altered tension of the membrana tympani. Attention was not called to the fact, however, that there was a simultaneous pressure upon the elastic membrane of the round window and upon the foot-plate of the stapes with its bordering membrane, which also caused a pressure on the contents of the labyrinth. To prove, as the author had supposed, that a change of pressure took place in the labyrinth when the air-pressure was increased or decreased in the tympanic cavity, he performed a number of manometrical experiments on fresh human ears in Professor Ludwig's

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* By means of experiments on vivisected dogs, the author was able to observe a widening of the fissure of the tube in the lateral pharyngeal wall by irritation of the trigeminus in the cranial cavity. The dissection showed that the widening was caused by the tensor palati muscle. ('*Ueber eine Beziehung des Trigeminus zur Eust. Ohrtrompete,*' *Würzburger naturw. Zeitschr.,* 1861.

† *Diseases of the Ear,* 1860.

laboratory. In these experiments, the condensation and rarefaction of air in the tympanic cavity were produced by an air-pump (Fig. 61) connected with the Eustachian tube (c). A small manometrical tube partly filled with a carmine solution (h) was introduced into the superior semicircular canal and hermetically sealed with wax. When the air in the tympanic cavity was condensed, an outward curvature of the membrana tympani and a rise of the fluid in the tube (h) (positive fluctuation from $1\frac{1}{2}$–3 mm.) were observed; when, however, the air in the tympanum was rarefied, a marked fall in the fluid was noticed. If the fenestra rotunda was closed with wax, a decrease in the fluctuation of the fluid in the tube took place during condensation of the air in the tympanic cavity. When the articulation of the stapes and incus was severed, an increase in the fluctuation of the fluid to the extent of $\frac{1}{2}$–$1\frac{1}{2}$ mm. resulted, in consequence of the removed resistance. This resistance is brought about by a simultaneous outward motion of the membrana tympani and malleus, which prevents the foot-plate of the stapes from advancing too far towards the vestibule. Bezold, whose manometrical
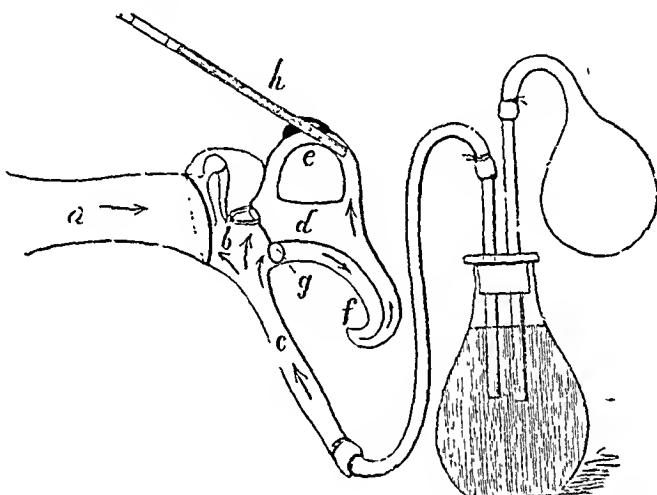
FIG. 61.—A SCHEMATIC VIEW OF THE ORGAN OF HEARING.

a, External meatus; b, Tympanic cavity; c, Eustachian tube; d, Vestibule of the labyrinth; e, The superior semicircular canal with the manometrical tube introduced into it (h); f, The cochlea with the scala vestibuli and tympani; g, Fenestra rotunda.

experiments led to similar results, found that the membrane of the fenestra rotunda was capable of an excursion of more than $\frac{1}{2}$ mm., while that around the base of the stapes was only $\frac{1}{10}$ mm. The membrane of the fenestra rotunda is therefore capable of performing excursions five times greater than that of the foot-plate of the stapes.

From these experiments it is shown:

1. That an alteration in the tension of the membrana tympani takes place by condensation of the air in the tympanic cavity, and also that the pressure on the contents of the labyrinth is considerably increased by a simultaneous action on the membrane of the fenestra rotunda and on the movable foot-plate of the stapes. The endings of the auditory nerve, surrounded by the endolymph, are mechanically irritated by this increased pressure, which becomes apparent as subjective noises. The slight degree of deafness which accompanies these noises can be compared to the disappearance of the perception of light when moderate pressure is exerted with the finger on the eyeball. The fact that in such cases hardness of hearing occurs, especially for

low tones, while high ones are comparatively well heard, can be explained by the altered tension of the sound-conducting apparatus; one must not forget, however, that the structures of the labyrinth (*lamina spiralis membranacea*) are at the same time more tightly stretched, and thereby vibrate with greater difficulty in response to low tones.

2. From the above experiments, explanation is found for the subjective noises and disturbances of hearing so often accompanying those diseases of the ear in which the two fenestræ of the labyrinth are abnormally weighted by the accumulation of serous, mucous, or purulent exudates, or by the formation of connective tissue in the tympanic cavity, or where the membrana tympani and ossicles are pressed inwards, thereby abnormally increasing the pressure in the labyrinth.

F. The Function of the Intratympanic Muscles.

Our present knowledge concerning the action of the intratympanic muscles is confined to the mechanism of the increase and decrease in the tension of the membrana tympani, and to the regulation of the intratympanic pressure. It has not yet been demonstrated what part they take in the act of hearing. In order to ascertain what influence the tensor tympani had upon the perception of tones, the author showed (*A. f. O.*, vol. i.) that, when testing with low and middle-ranged tuning-forks, a muffling of the key-notes and a more distinct perception for the overtones was observed. These experiments were carried out on human ears, as well as on those of recently killed dogs, in which the tensor was made to contract by electrical irritation of the trigeminus in the cranial cavity.

Hensen and Bockendahl,[*] who opened the cavum tympani of vivisected dogs, and attached a light, sensitive lever to the tendon of the tensor tympani muscle, observed reflex contractions of that muscle on sounding musical tones. J. Pollak,[†] who substantiated these results, found that the energy of the contractions was generally greater for high than for low tones; furthermore, that the contractions were strongest for the vowel *a*, very slight for *u*, and that through the action of tones on one ear a reflex contraction of the muscle in the other ear was observed. The reaction of the tensor tympani muscles disappears completely with destruction of both labyrinths. Hammerschlag has recently shown by extensive experiments that the action of the tensor reflex is independent of the cerebrum, and furthermore, that the path of the reflex, from the acoustic to the trigeminus nucleus, is represented by the corpus trapezoides, and not by the striæ acusticæ. These experiments did not relate so much to the function of the tensor tympani as to the physiological conditions of its reflex movements. Ostmann (*Pflüger's Arch.*, 1898) was the first to observe, in the intact drum membrane of man, reflex contractions of the tensor tympani muscle.

The author has experimentally (*loc. cit.*) proved that the action of the tensor is not confined to the membrana tympani alone, but also to the labyrinth, inasmuch as he observed a motion of the fluid in the labyrinth on electrical irritation of the root of the trigeminus. The tensor tympani, therefore, increases the pressure in the labyrinth. The stapedius muscle, on the other hand, must be regarded as the antagonist of the tensor tympani, as the author has shown by irritation of the facial nerve in the cranial cavity (*Wiener Medicinalhalle*, 1867); it relaxes the tympanic membrane, and diminishes the pressure in the labyrinth.

From experiments conducted hitherto, we can only state that one of the principal functions of the intratympanic muscles is to govern changes in the position and tension of the ossicular chain and abnormal pressure in the labyrinth, which are brought about by the variable fluctuations in the air-

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[*] *Arch. f. Ohrenheilk.*, vol. xvi.   [†] *Med. Jahrbücher.* Wien, 1886.

pressure in the external and middle ear. They therefore regulate the degree of tension of the hearing apparatus. Lucæ's* theory that the tensor tympani serves to accommodate the hearing apparatus for loud musical tones and musical noises, while the stapedius muscle regulates the organ of hearing for weak sounds, has not been experimentally proven.

As the result of observations made on himself and on patients (*A. f. O.,* vol. iv.), the author was the first to state that the deafness which occurs during yawning is brought about by a simultaneous contraction of the tensor tympani. This view was confirmed by Helmholtz (*loc. cit.*).

Voluntary contractions of the tensor tympani have been observed in only a few cases (Schwartze, *A. f. O.,* vol. ii., and Lucæ, *ibid.,* vol. iii.). In a case published by the author, involuntary and voluntary contractions of the tensor were observed in both ears. The cracking noises in the ear which some persons can produce voluntarily are mostly caused by the contractions of the abductor tubæ, rarely, however, by the contractions of the tensor tympani (Luschka, Politzer).

Lucæ first observed that the contractions of certain muscles of the face, particularly the musculus orbicularis, can produce a simultaneous contraction of the stapedius. This is made evident by a deep humming sound in the ear, and also by a relaxation of the tympanic membrane, as shown by the manometer. During such reflex contractions the perception for the lower and middle tones of the tuning-fork is lost.†

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* *Chron. progr. Schwerhörigkeit.* Berlin, 1907.
† Compare also Ostmann, *Arch. f. Anat. und Physiol., phys. Abt.,* 1899.

THE ANATOMY AND PHYSIOLOGY OF THE SOUND-PERCEIVING APPARATUS.

III. THE INTERNAL EAR.

THE internal ear or sound-perceiving apparatus is made up of the terminal filaments of the auditory nerve in the labyrinth, the trunk of the auditory nerve, and its central origin in the brain.

A. The Labyrinth.

This part of the ear consists of a membranous labyrinth enclosed by an osseous capsule.

1. The Osseous Labyrinth.

The osseous labyrinth comprises the vestibule, the three semicircular canals, and the cochlea, to which may also be added the internal auditory canal.

(a) **The Vestibule.**—The vestibule is an irregular, elliptical cavity which communicates anteriorly with the cochlea, and posteriorly with the semicircular canals. It is 5–6 mm. in length, 3–4 mm. in width, and 4–5 mm. in height. Its walls merge into each other without any line of demarcation. The lateral wall (Fig. 63) is partly formed by the fenestra ovalis; the latter is 3 mm. in length, and 1½ mm. in width, and is closed by the foot-plate of the stapes (*st*). On the medial wall, which is directed towards the base of the internal auditory canal, are two recesses, separated by the crista vestibuli; these receive the utricle and saccule. The anterior, smaller one (2–3 mm. in diameter) is called the *recessus sacculi*; the posterior, larger (4–5 mm. in length, and 3 mm. in width), the *recessus utriculi*. The upper end of the crista vestibuli, lying opposite the fenestra vestibuli, is termed the *pyramis vestibuli*. In addition to these two recesses, a small opening is found on the inner wall of the labyrinth—the vestibular opening of the aquæductus vestibuli—from which a grooved depression extends towards the inferior wall of the vestibule. On the posterior, and partly also on the superior inferior and internal walls of the vestibule are the openings of the semicircular canals (Fig. 64); these consist of three larger ampullar orifices and two smaller openings. The ampullar orifice of the superior (*as*) and that of the horizontal (*ah*) semicircular canal lie next to each other on the superior wall of the vestibule above the fenestra ovalis, the former lying above that of the latter. The ampulla of the posterior semicircular canal (*s*)

lies on the floor of the vestibule in the region of the orifices of the horizontal (*h*) and the common opening of the superior and posterior semicircular canals (*co*). The ampullar orifices are separated from the vestibular walls by projecting ridges—the *cristæ ampullarum*. On the inferior wall of the vestibule, below the fenestra ovalis, the beginning of the lamina spiralis ossea and membranacea is seen (Fig. 63, *sp*) extending with a slight bend from within outwards towards the entrance of the scala vestibuli. On the macerated temporal bone, by destruction of the commencement of the membranous spiral plate, a cleft is formed through which the vestibule communicates with the scala tympani of the cochlea. On the anterior border of the external and inferior vestibular walls another opening is found which leads into the scala vestibuli of the cochlea (Fig. 63, *v*). On the crista vestibuli, as well as on the floor of the two recesses, the so-called *maculæ cribrosæ* are found, each of which is composed of a number of openings which are intended for the passage of the filaments of the vestibular nerve. The *macula cribrosa superior* is for the passage of the nerves of the utricle and of the ampullæ of the superior (frontal) and horizontal semicircular canals; the *macula cribrosa media* for the nerves of the saccule; and the *macula cribrosa inferior* for the nerves of the ampulla of the posterior (sagittal) semicircular canal.
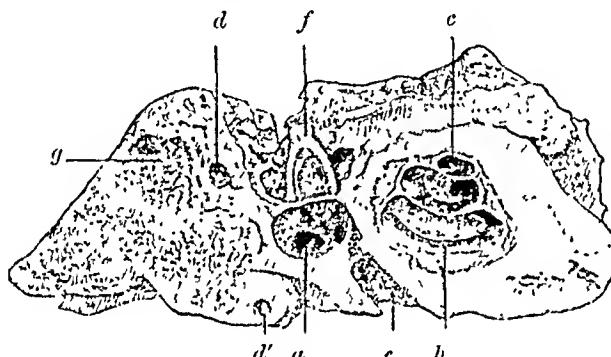
FIG. 62.—HORIZONTAL SECTION THROUGH THE PETROUS BONE OF A NEW-BORN CHILD. (TWICE THE ACTUAL SIZE.)

a, Vestibule; *b*, Base of the cochlea; *c*, Cupola of the cochlea; *d*, *d'*, Sections of the superior semicircular canal; *e*, Internal auditory meatus; *f*, Stapes; *g*, Antrum tympanicum.

(*b*) **The Semicircular Canals (Canales Semicirculares).**—The three semicircular canals lie behind the vestibule in the osseous mass of the petrous portion of the temporal bone, and form with their planes standing perpendicularly to each other a solid angle. There is a superior (frontal), a posterior or internal (sagittal), and a horizontal or external (lateral) semicircular canal. The convexity of the superior (frontal) semicircular canal (Fig. 66, *c*) is turned towards the superior surface of the pyramid, and forms a marked bulging (*eminentia arcuata*), the highest point of which does not correspond exactly to that of the semicircular canal. The convexity of the external (sagittal) semicircular canal (*e*) is turned backwards, and its plane lies nearly parallel to the posterior wall of the pyramid. The convexity of the external or horizontal semicircular canal (*g*) is also turned backwards; the external portion of this canal forms a prominence on the internal wall of the tympanic cavity behind the facial canal. In cases of chronic middle-ear suppuration a fistula is sometimes formed at this place.

According to the investigations of Schwalbe, the length of the semicircular canals varies greatly. The posterior semicircular canal is the longest, and according to this author the relations of the posterior, superior and horizontal semicircular canals is about 6 : 5 : 4. The semicircular canals and the

ampullæ are elliptical in cross-section, the lumen of the canals being greatest at the point where they pass into the ampullæ.

Each of the three semicircular canals begins with an ellipsoidal dilatation, 1½–2 mm in size, the so-called *osseous ampullæ* of the semicircular canals
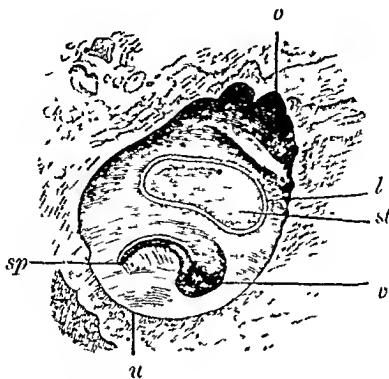
FIG. 63.—SAGITTAL SECTION THROUGH THE VESTIBULE : VIEW OF ITS LATERAL WALL.

o, Upper wall; *u*, Lower wall; *sl*, Fenestra ovalis with the foot-plate of the stapes; *l*, Ligamentum orbiculare stapedis; *sp*, Beginning of the lamina spiralis ossea and membranacea on the lower vestibular wall; *v*, Entrance into the scala vestibuli of the cochlea. From a preparation in the author's collection.

(Fig. 66, *d*, *f*, *h*). The three canals open into the vestibule by only two orifices, inasmuch as the superior (*c*) and the posterior (*e*) unite into one common canal before entering the vestibule.

(c) **The Cochlea.**—The cochlea (Fig. 66, *i*) is a canal 28–30 mm. long, which gradually becomes smaller towards its superior extremity; it turns a
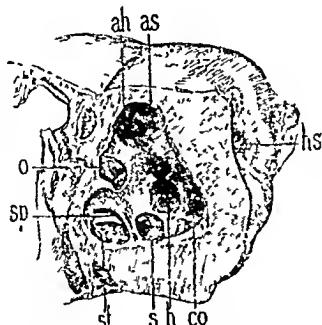
FIG. 64.—FRONTAL SECTION THROUGH THE VESTIBULE: VIEW OF THE POSTERIOR VESTIBULAR WALL. (ENLARGED TO DOUBLE ITS NATURAL SIZE.)

o, Fenestra ovalis; *ah*, Ampulla horizontalis; *as*, Ampulla superior; *s*, Ampulla orifice of the posterior semicircular canal; *h*, Opening of the horizontal semicircular canal; *co*, Common opening of the superior and posterior semicircular canals; *sp*, Commencing portion of the lamina spiralis in the vestibule; *st*, Scala tympani of the cochlea; *hs*, Fossa subarcuata. From a preparation in the author's collection.

little more than two and a half times round its axis, and on cross-section presents the form of an ordinary garden snail. In macerated specimens the cavity of the cochlea is seen to communicate with the vestibule by a spacious opening (Fig. 63, *v*), and with the tympanic cavity by means of the round window.

With its spiral winding, the cochlea is so embedded in the petrous portion of the temporal bone between the internal meatus and the carotid canal, that its base is turned inwards towards the internal auditory canal and its apex (*cupola*) outwards towards the tympanic cavity.

On vertical sections of the cochlea (Fig. 67), one sees, in addition to the openings of its windings, the modiolus (*b*), which begins with a broad base at
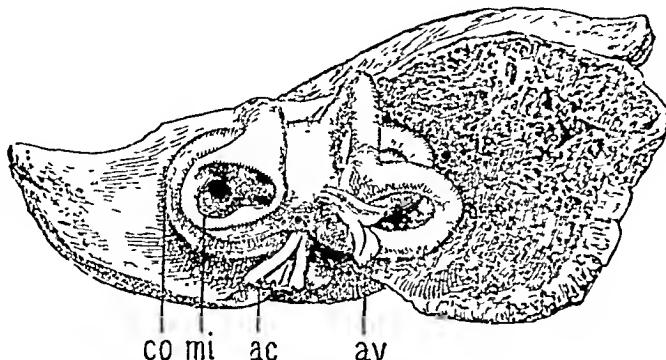
FIG. 65.—POSTERIOR VIEW OF THE OSSEOUS LABYRINTH OF A NEW-BORN INFANT, WITH THE THREE SEMICIRCULAR CANALS, THE COCHLEA, AND THE AQUEDUCTS. (ENLARGED TO DOUBLE ITS SIZE.)

co, Cochlea; *mi*, Internal auditory canal; *ac*, Aquæductus cochleæ; *av*, Aquæductus vestibuli. From one of Ilg's preparations in the Anatomical Museum of Vienna.

the bottom of the internal auditory canal and, gradually becoming smaller, extends nearly to the superior extremity of the cochlea (cupola). It is developed, just as the lamina spiralis ossea, from a connective-tissue ground substance, while the external covering of the capsule of the cochlea is formed by the hyaline primordial cartilage (Böttcher). Moos and Manasse found
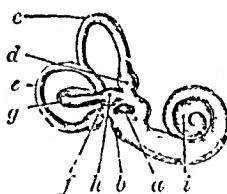
FIG. 66.—CAST OF THE OSSEOUS LABYRINTH.

a, Fenestra ovalis; *b*, Fenestra rotunda; *c*, Superior semicircular canal; *d*, Its ampulla; *e*, Posterior semicircular canal; *f*, Its ampulla; *g*, Horizontal semicircular canal; *h*, Its ampulla; *i*, Cochlea.
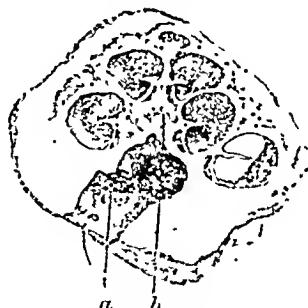
FIG. 67.—SECTION OF THE OSSEOUS CAPSULE AND OF THE MODIOLUS OF THE COCHLEA WITH THE LAMINA SPIRALIS OSSEA.

a, Internal auditory meatus; *b*, Modiolus.

fully-developed cartilage cells in the capsule of the cochlea, and the author also observed cartilage cells in the supporting trabeculæ which connect the modiolus with the cochlear capsule.

The axis of the modiolus is traversed from its base to the cupola by numerous neural and vascular canals. In the centre of the modiolus the *canalis centralis modioli* runs from the base to the apex; on the external surface, encircling the modiolus, is the *canalis spiralis sive ganglionaris*

(Rosenthal), which contains the spiral ganglion and a spiral vein. The lamina spiralis ossea rises from the external surface of the modiolus; this is an osseous plate placed at right angles to the modiolus, which, beginning between the round window and the inferior wall of the vestibule, extends in a spiral manner to the cupola, where it ends in the pointed *hamulus*. To this the membranous spiral lamina is attached. The canal of the cochlea is divided by this membrane into two divisions, the superior of which (*scala vestibuli*) communicates with the vestibule, while the inferior (*scala tympani*) ends at the fenestra rotunda, which is closed by the *membrana tympani secundaria*. The scalæ communicate with each other at the apex of the cochlea through the *helicotrema* (Breschetii).

All the spaces of the labyrinth are lined with a layer of connective tissue intermixed with fine elastic fibres.

(*d*) **The Internal Auditory Canal.**—The internal auditory canal presents many individual variations in length and width. Its course from the oval opening on the posterior surface of the pyramid (Fig. 62, *e*) is directed markedly outwards and backwards. The inner end is divided by a transverse ridge into a superior and inferior fossa. In the anterior part of the superior fossa is the entrance to the facial canal, and in the posterior part the openings for the passage of the vestibular nerves. In the inferior depression (*fossa cochleæ*, Fig. 67) the spirally arranged openings (*tractus spiralis foraminulentus*) at the base of the cochlea can be seen, which serve as the place of entrance for the fibres of the cochlear nerve. In addition to this, a small group of openings is found on the posterior wall of the internal auditory meatus, through which several branches of the vestibular nerve pass.

2. The Membranous Labyrinth.

The membranous labyrinth, which is surrounded by an osseous capsule—namely, the bony labyrinth—consists of the saccule and utricle, the three membranous semicircular canals, and the membranous portion of the cochlea.

(*a*) The Saccule and Utricle.

The vestibular sacs are two in number, and are termed the utricle and saccule; the former is in communication with the semicircular canals (Figs. 68 and 69), while the latter is in direct connection with the canal of the cochlea. The utricle (*sacculus hemiellipticus*), 5–6 mm. in length and elongated, lies in the recessus ellipticus, and is in direct communication with the membranous semicircular canals by means of five orifices. It extends from the roof of the vestibule (Fig. 72) to the entrance of the posterior ampulla, and runs from in front and above, backwards and downwards. It is divided into three parts, of which the superior is the recessus utriculi (Fig. 69, *re*), which is 3–3·5 mm. in breadth and length, while the other two portions are formed by the utriculus proprius, which is 3 mm. long and 1·5–2 mm. broad. The ampullæ of the superior and lateral semicircular canals open into the recessus utriculi, and the ampullæ of the posterior semicircular canal and the sinus utricularis superior into the utriculus proprius. A yellow elevation, about 3 mm. long and 2–3 mm. wide, known as the *macula acustica utriculi* (Figs. 70, *na*, and 72, *ma*), is situated on the lateral and anterior walls of the recessus utriculi.

The round saccule (*S. sphæricus s. rotundus*) lies in the anterior portion of the vestibule in the recessus sphæricus. It is in communication with the ductus cochlearis by means of the ductus reuniens (Hensen), a small tube 0·7 mm. long and 0·22 mm. wide (according to Retzius, 1 mm. long and 0·5 mm. wide). The *macula acustica sacculi*, which is located on its medial surface, has a breadth of 1–2 mm. Alexander found in the ductus reuniens of the embryo (guinea-pig) the beginning of a macula acustica which recedes

in the further course of development, and which must be regarded as the homologue of the macula lagenæ of the fish and amphibians.

The vestibular cul-de-sac of the cochlea is seen as a protrusion of the canals of the cochlea, and develops at a comparatively later stage.

The saccule and utricle consist of a fibrillated connective-tissue layer, to which a structureless, homogeneous, hyaline membrane and an epithelial layer are attached. The connective-tissue layer is most fully developed at the maculæ acusticæ. The epithelial stratum is formed by a simple layer of squamous epithelium. This variety becomes cylindrical at the maculæ acusticæ, and then passes into neuro-epithelium (Fig. 71), which is composed
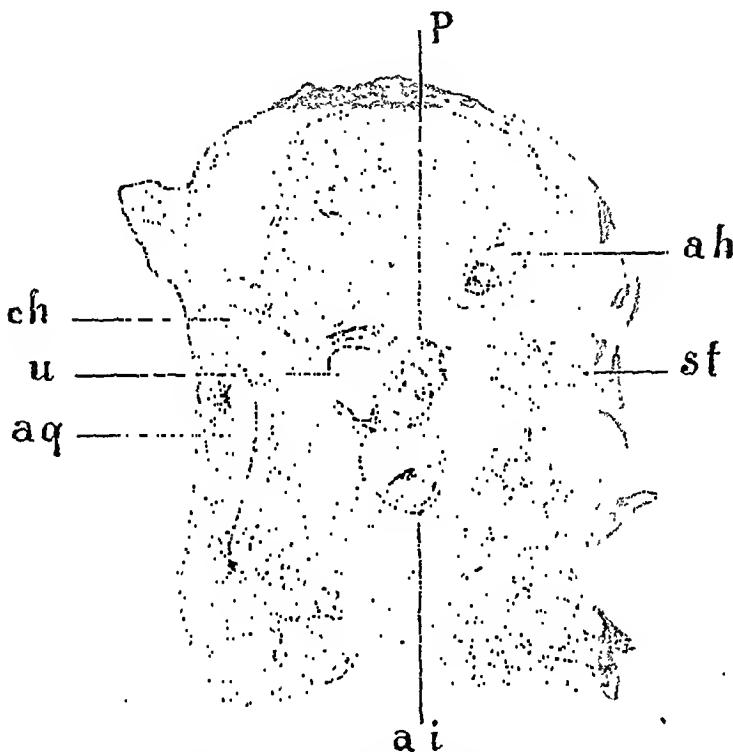
FIG. 68.—FRONTAL SECTION THROUGH THE POSTERIOR PORTION OF THE VESTIBULE BEHIND THE FENESTRA OVALIS.

u, Utriculus; *p*, Cisterna perilymphatica; *ah*, Ampulla horizontalis; *ch*, Section of the horizontal semicircular canal; *ai*, Ampulla inferior (sagittal semicircular canal); *st*, Stapes; *aq*, Section of the aquæductus vestibuli. From a preparation in the author's collection.

of acoustic and fibre cells (Hasse's *Isolationszellen*). The former—namely, the acoustic cells—have a bottle-shaped appearance, with a bulging in the middle and a projection of the free extremity. The structures known as the auditory cilia consist, according to Retzius, of ten to fifteen filaments, which are 20–25 μ in length. The elliptical nucleus lies in the bulged portion of the cell. The cylindrical fibre cells have a round nucleus which is found near the base. The terminations of the vestibular nerve in the saccule and utricle have been thoroughly investigated by Urban Pritchard—*The Termination of the Nerves of the Vestibule and Semicircular Canals* (*Quarterly Journal for Medical Science*, 1876). According to him, the medullated nerve fibres undergo extensive anastomoses, and broaden out in the connective-tissue layer of the maculæ acusticæ; from here several non-nucleated nerve filaments penetrate

the basilar membrane and wind their way, as very delicate granular fibrillæ, between the supporting cells (fibre cells, Retzius) of the epithelium to the inferior nucleated, rounded extremity of the hair-cells. According to the investigations of Katz, the fibrillæ make a turn at this place, running in an almost horizontal direction, and form a narrow nerve plexus, whence they supply the inferior part of the hair-cells, which they surround in the form of a cup (Retzius, Kaiser). In sections which have been taken from young mice, and stained by Golgi's method (v. Lenhossek, Katz), several nerve fibres can be seen to extend to the limit of the section. The union of the vestibular nerve with the hair-cells takes place by contact. The epithelium of the maculæ acusticæ is covered by a clear, transparent, semi-fluid substance
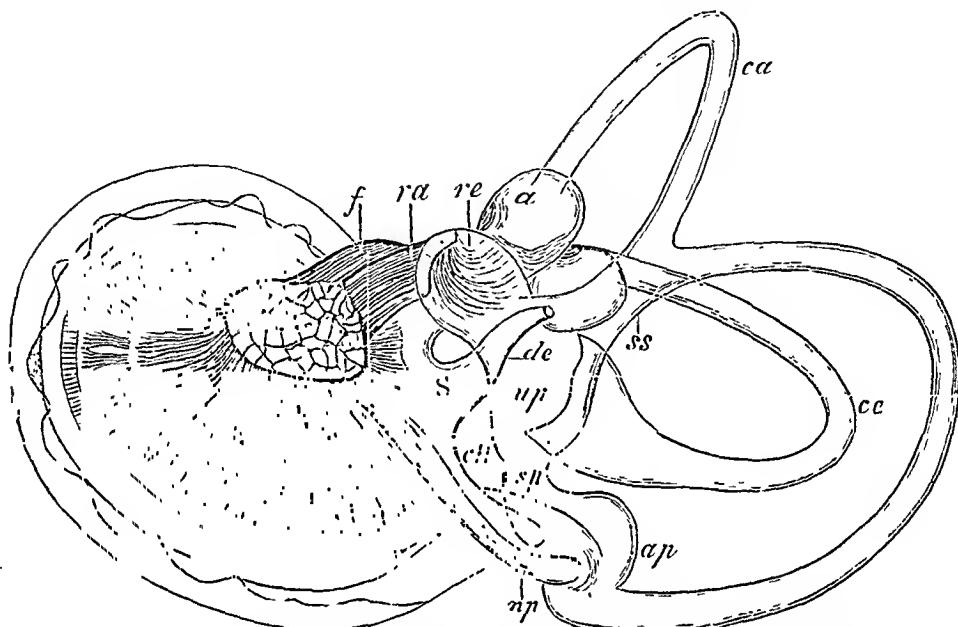
FIG. 69.—THE MEMBRANOUS INTERNAL EAR OF A HUMAN EMBRYO FIVE MONTHS OLD. ENLARGED TEN TIMES (FROM BEHIND AND WITHIN). (AFTER RETZIUS.)

up, Utriculus proprius; *rc,* Recessus utriculi; *S,* Sacculus; *ss,* Sinus utriculi superior; *sp,* Sinus utriculi posterior; *cII,* Canalis reuniens Henseni; *a,* Ampulla anterior; *ap,* Ampulla posterior; *ca,* Canalis semicircularis anterior; *cc,* Canalis semicircularis lateralis; *de,* Ductus endolymphaticus; *ra,* Nervus vestibularis; *f,* Nervus facialis; *np,* Nervus ampullaris inferior.

(Steinbrügge) which coagulates after death, and which, in the form of a membrane, surrounds the otoliths or otoconia; these consist of small hexagonal crystals of carbonate of lime. Schwalbe found small vacuoles in the middle of the otoliths.

The walls of the utricle are united to the superior and medial walls of the vestibule by means of delicate, finely-meshed connective tissue (Figs. 70, 72), and in a like manner the saccule is connected with the medial wall of the recessus sphæricus. Between the utricle and saccule and the lateral wall of the vestibule (Fig. 72, *c*) a considerable perilymphatic space is found (Steinbrügge), which Retzius terms the *cisterna perilymphatica vestibuli.**

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* In order to study the comparative anatomy of the membranous labyrinth, the author recommends the original work of: Retzius, *Gehörorgan der Wirbeltiere,* Stockholm, 1881 and 1884; Kuhn, *Beiträge zur Anatomie*

(b) The Membranous Semicircular Canals.

Their form (Fig. 73) corresponds to that of the osseous semicircular canals. A slight constriction at the external surface of each ampulla designates the place of entrance of the ampullar nerve. Corresponding to this constriction there is found, on the inner side of the ampulla, an elevation which is known as the *crista ampullaris* (Fig. 70, a). This elevation divides the space of the ampulla into two unequal portions, the shorter of which, directed towards the utricle, is designated by Steifensand as the sinus portion, the longer as the tubal portion. The ampullæ are covered with epithelium, which is partly
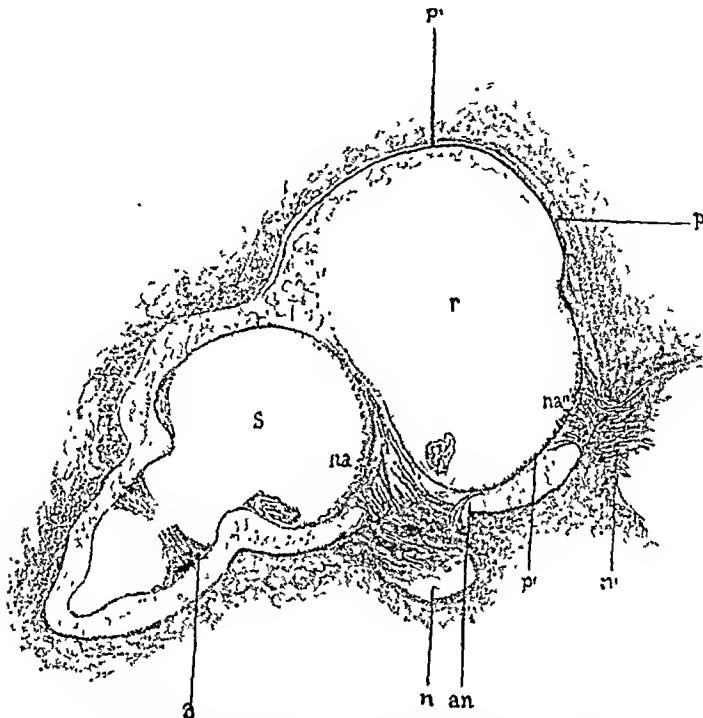
FIG. 70.—HORIZONTAL SECTION THROUGH THE VESTIBULE ABOVE THE FENESTRA OVALIS OF A NEW-BORN INFANT.

s, Utriculus; *a*, Ampulla externus and the crista ampullaris discharging into it; *r*, Space in which the sacculus is situated; *n*, Nerve bundles of the ramus vestibuli passing to the utriculus and the macula acustica utriculi; *p, p'*, Adherent wall of the sacculus (incompletely cut through); *n''*, Nerve bundles passing to the macula acustica sacculi; *an*, Nerve anastomoses running from the nerve bundle *n* to *n'*. From a preparation in the author's collection.

squamous and partly cylindrical; in addition to this, however, we find at the epithelial ridge of the crista (*planum semilunatum*, Steifensand) high cylindrical cells, and a neuro-epithelium analogous to that found on the maculæ acusticæ of the saccule and utricle.

The membranous semicircular canals, the diameter of which is about one-third that of the osseous canals, are not suspended, as was formerly supposed,

des Gehörorgans, Bonn, 1880; C. Hasse, *Die vergleichende Morphologie und Histologie des häutigen Gehörorgans der Wirbeltiere*, Leipzig, 1873; A. Tafani, *Organo del' udito*, Firenze, 1886; G. Alexander, *Entwicklung und Bau der Pars inferior labyrinthi der Säugetiere*, Denkschriften der k. Akademie, 1900, vol. lxx.

in the latter, which are filled with perilymph; they are (Fig. 74) attached as was shown by Scarpa and Breschet, to the external side of the bony canals by a part of their walls, and are thus made stationary. Inconstant, vascular, connective-tissue bands (Fig. 75, *d*) (ligaments) extend from the free portion of the membranous semicircular canals through the perilymphatic space to the periosteum of the osseous canals. Numerous papillary elevations covered with epithelium (*c*) arise on the inner surface of the membranous canals; these are lacking at the adherent parts of the canals (*b*) and at their place of entrance into the utricle (Rüdinger). The papillary elevations are covered with polygonal epithelium, which assumes a more cylindrical form on the striæ (raphé) which lie on the concave side of the semicircular canal and
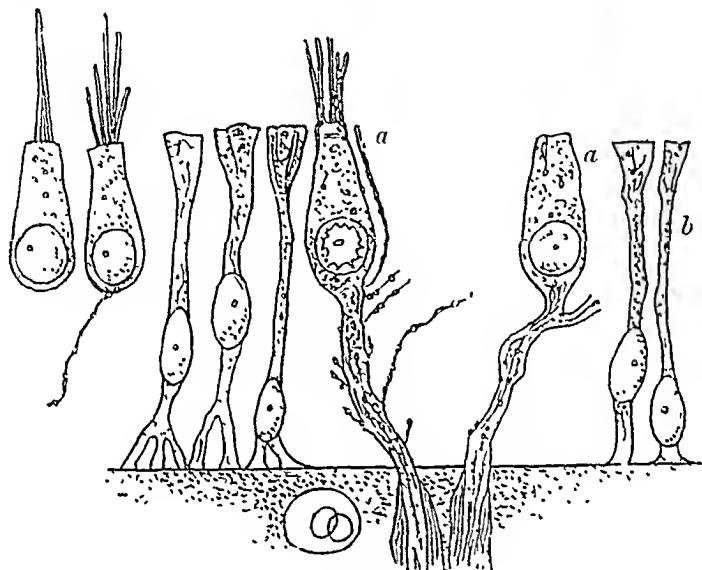
FIG. 71.

a, Hair-cells (after Retzius); *b*, Fibre cells.

extend into the ampullæ. Nerve elements have not been found in the semicircular canals. Alexander[*] has observed in the perilymphatic connective tissue of a number of young mammals collections of pigment which were regular in shape and arrangement.

(*c*) **The Membranous Structures and the Terminations of the Acoustic Nerve in the Cochlea.**

The terminal structure of the cochlear nerve, known as the organ of Corti, lies upon the membranous spiral lamina, which arises from the free border of the lamina spiralis ossea (Fig. 76) and is inserted into the ligamentum spirale (Fig. 76, *l*, and 77, *tr*), projecting from the opposite wall of the cochlea. The membranous spiral lamina is divided into three sections: the inner, which is perforated by numerous orifices for the passage of the fibres of the cochlear nerve (*zona perforata, p*); the middle, which bears the organ of Corti (*zona arcuata*); and the outer, which is finely striated (*zona pectinata*).

We have seen that the canal of the cochlea is divided by a spiral plate into the scala vestibuli (Fig. 76, *sc v*) and the scala tympani (Fig. 76 *sc. t*). The

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[*] Compare Alb. A. Gray, *The Labyrinth of Animals*, vol. i. London, Churchill, 1907.

former is again divided into two compartments by the *membrana vestibularis* (Reisneri, *R*), which runs from the upper surface of the lamina spiralis ossea to the external wall of the cochlea. The space bounded by the basilar membrane, the external wall of the cochlea and the membrana vestibularis is known as the (*canalis*) *ductus cochlearis* (Fig. 76, *Dc*). This canal, which is lined by a layer of epithelium and contains the terminal filaments proper of the nerve, is filled with endolymph, communicates with the saccule by means of the ductus reuniens, and ends in a cul-de-sac below the cupola of the cochlea.
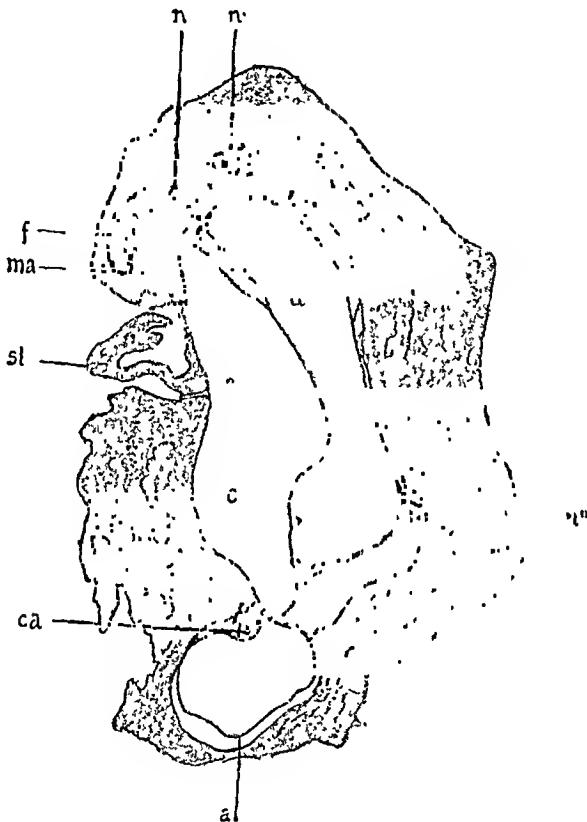
Fig. 72.—Frontal Section through the Vestibule and the Fenestra Ovalis of a New-born Infant.

u, Utriculus attached to the medial and upper walls of the vestibule; *ma*, Free lateral wall of the utriculus, with the macula acustica; *st*, Fenestra ovalis and stapes; *c*, Space between the utriculus and the lateral vestibular wall—cisterna perilymphatica; *n*, *n'*, *n''*, Nerve bundles of the nervus vestibularis passing to the utriculus and ampullæ; *a*, Ampulla inferior; *ca*, Crista ampullaris; *f*, Nervus facialis. From a preparation in the author's collection.

In order to study the details of Corti's organ, it is best to make microscopic sections which are cut perpendicularly to the lamina spiralis through the axis of the cochlea (Fig. 77). At the inner part of such a profile view of the lamina spiralis, a swelling produced by a thickening of the periosteum can be seen, which resembles a cock's comb (*H*), and has a toothed ridge (*crista spiralis*, Huschke). It roofs over a canal running a spiral course (*sulcus spiralis internus*), which is lined with cuboidal epithelium (*K*). The external wall of the ductus cochlearis is formed by the ligamentum spirale, at the upper end of which (Fig. 76) the membrana vestibularis (*R*) is inserted.

This ligament consists of a connective-tissue base, which is very vascular. A sharply defined strip, the *stria vascularis,** covered with epithelial cells, and rich in bloodvessels, extends towards the lumen of the ductus cochlearis. This strip is joined at its basilar part by a row of cells, which borders on a furrow lying opposite the sulcus spiralis (*sulcus spiralis externus*).

External to the sulcus spiralis lies Corti's organ proper (Fig. 77). This consists of an inner (*C*) and an outer (*C'*) row of gently curved rods (Corti's fibres), the lower extremities of which rest upon the basilar membrane, while their upper ends articulate with each other. The two rows form the tunnel of Corti's organ; the inner are broader than the outer, so that we find two of the former to three of the latter. In the lower angle, formed by the rods and basilar membrane, two rows of round nucleated cells (basilar cells) are found.

The outer row of rods has a plate-shaped process at its upper extremity, to which a net-like perforated membrane, the *lamina reticularis* (*r*), is attached. This roofs over the external rods and the so-called Corti's cells, or
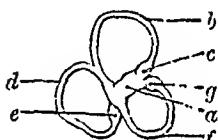
FIG. 73.—MEMBRANOUS LABYRINTH.

a, Utriculus; *b,* Superior semicircular canal; *c,* Its ampulla; *d,* Posterior semicircular canal; *e,* Its ampulla; *f,* Horizontal semicircular canal; *g,* Its ampulla.
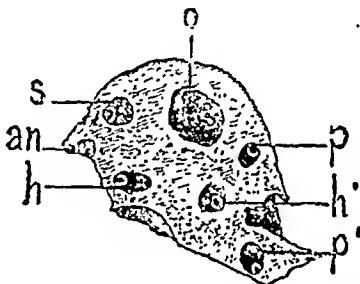
FIG. 74.—TOPOGRAPHICAL POSITION OF THE MEMBRANOUS WITHIN THE OSSEOUS SEMI-CIRCULAR CANALS: TRANSVERSE SECTION THROUGH THE POSTERIOR PART OF THE DE-CALCIFIED PYRAMID OF A NEW-BORN INFANT. (RIGHT EAR.)

s, Transverse section of the superior semicircular canal; *h, h',* Transverse sections of the horizontal semicircular canal; *p, p',* Transverse sections of the posterior semicircular canal; *o,* Fossa subarcuata; *an,* Inner wall of the mastoid antrum. From a preparation in the author's collection.

external hair-cells (*äh*). The latter structures (*Z*) (Retzius), which in man are arranged in three, four, in rare cases five, parallel rows (Gottstein), are surrounded by the terminal fibres of the acoustic nerve (Retzius) in the form of a network; they are attached to the basilar membrane by their delicate, elongated inferior extremities (Gottstein's basilar process), while their upper wider ends are covered with auditory hairs, which project through the openings of the lamina reticularis. A row of inner hair-cells (*ih*) is found in front of the sulcus spiralis internus immediately anterior to the inner rods of Corti's organ. According to H. Joseph (*Anatom. Hefte,* vol. xiv.), peculiar hornified bodies (*Pfeilerkopfeinschlüsse,* Joseph) are enclosed in the upper joint-like ends of the rods (Köpfen). These are found in a number of animals, and probably also in man; their marked hardness may perhaps give them

* Katz, *Histologisches über den Schneckencanal, spec. die Stria vascularis* (*Verhandl. des X. internat. med. Congress,* Berlin, 1890), and Shambough, *Trans. of the American Otol. Soc.,* vol. x.

the function of a joint (Schwalbe, *Lehrb. d. Anat. d. Sinnesorg*). Deiters' cells (*D*), which have their broad extremities directed downwards, are joined to Corti's cells by branches in the form of tongs, which belong to the former and which grasp the latter (Katz). External to the last row of Corti's cells lio the supporting cells of Claudius and Hensen (*Cl*), which pass into tho epithelium of the external wall of the ductus cochlearis. By the aid of his own method, Held* found in the rods of Deiters' supporting cells and in other supporting elements around the hair-cells a complicated system of elastic supporting threads.

Corti's organ is covered by tho firm striated Corti's mombrane (Fig. 77, *cm*). This arises from tho crista spiralis of Huschke, alongside of and below the vestibular membrane, and ends, according to the gcneral opinion, at the
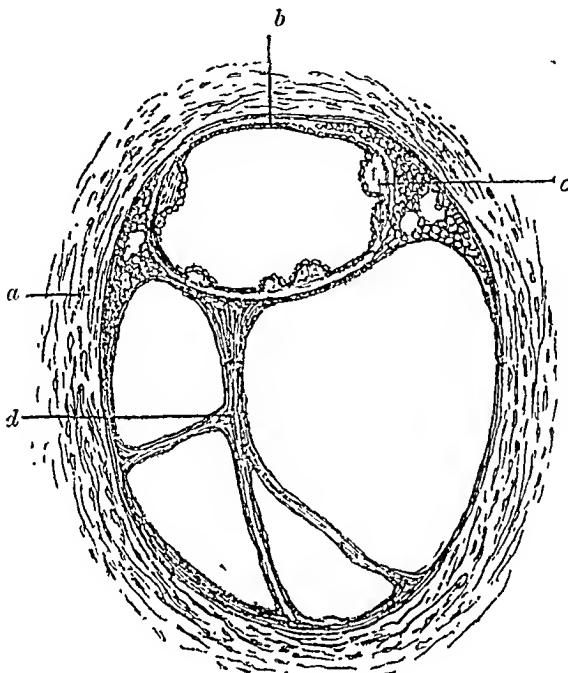
FIG. 75.—SECTION OF THE OSSEOUS AND MEMBRANOUS SEMICIRCULAR CANALS.

a, Osseous semicircular canal; *b*, Place of attachment of the membranous semi-circular canal; *c*, Globular clevations on the inner surface of the membranous semicircular canal; *d*, Vascular connective-tissue bands.

external boundary of the perception cells of Corti's organ. According to Böttehor (*A. f. O.*, vol. xxiv.), Corti's membrane is fixed by prolongations to the surfaco of tho terminal apparatus of the acoustic nerve.† Coyno and Cannieu consider Corti's membrane a cuticular formation, which arises from degenerated cilia.

The round window (*fenestra cochleæ*), situated at the posterior part of the promontory below the fenestra ovalis, is in intimate relation with the cochlea. This window is closed by a membrane, tho *membrana tympani secundaria* (Scarpa), which is somewhat bulged towards the interior of the cochlea, and

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* *Untersuchungen über den feinen Bau des Ohrlabyrinths der Wirbeltier, Abt. d. mathem. phys. Klasse d. Wissen.*, vol. xxviii.

† According to Kolmer, the auditory cilia of Corti's cells are in connection with the cortical membrane.

is inserted by a broad base into the *crista fenestræ rotundæ*. The form of the membrane when removed from the round window is convex above and somewhat concave below. The fibrillated lamina propria of the membrane is covered on its inner surface by a continuation of the labyrinthine lining, and on its outer surface by the mucosa of the tympanic cavity (Weber-Liel). The latter is highly developed in the new-born, and has occasionally, as the author was the first to observe, one or more vascular papillæ which are visible even to the naked eye.

The Ductus Endolymphaticus and Aquæductus Cochleæ.—The former, which was discovered by Domenico Cotugno in 1761, arises, according to Böttcher, by two thin membranous tubes from the utricle and saccule. These two membranous tubes unite into a common broad canal, 5–6 mm. long and 0·25 mm. wide, which passes through an opening in the inner labyrinthine wall into the narrow osseous portion of the aquæductus vestibuli.
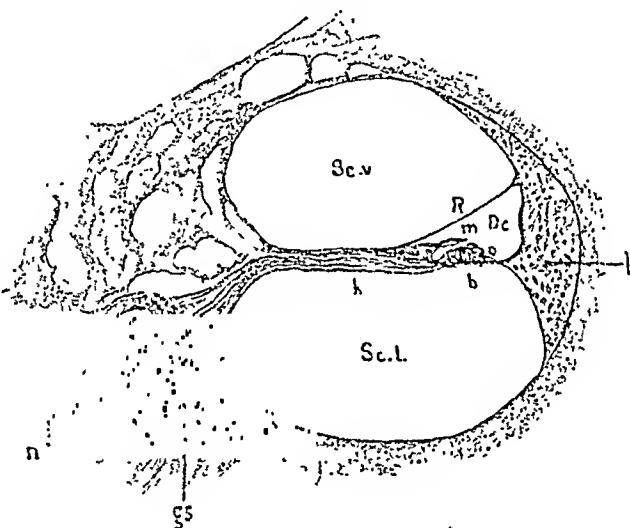
FIG. 76.—SECTION THROUGH THE FIRST TURN OF THE COCHLEA OF A NEW-BORN INFANT.

Sc. v, Scala vestibuli; *Sc. t*, Scala tympani; *k*, Lamina spiralis ossea; *b*, Lamina basilaris; *l*, Ligamentum spirale; *R*, Membrana vestibularis; *Dc*, Ramus cochlearis; *o*, Corti's organ; *m*, Corti s membrane; *n*, Fasciculus of the ramus cochleæ; *gs*, Ganglion spirale. From a preparation in the author's collection.

At the hiatus aquæductus vestibuli behind the internal auditory canal this small canal joins a blind sac in the dura mater about 15 mm. long and 9 mm. wide; the latter, running towards the sigmoid sinus (Fig. 78), is lined with a layer of epithelium, and communicates with the endolymph of the labyrinth (Zuckerkandl). According to Rüdinger, lateral canals branch off from the intradural sac of the aqueduct, which he thinks serve as drainage-tubes for the perilymph to the subdural lymph-spaces. The aquæductus cochleæ, about 10 mm. long, arises from a small opening in the scala tympani in the neighbourhood of the round window, and ends in a funnel-shaped enlargement near the inferior surface of the petrous portion of the temporal bone in the region of its posterior edge. It acts as the immediate means of communication between the arachnoid cavity and the perilymphatic fluid of the labyrinth. Weber-Liel, Schwalbe, and others, have shown experimentally that a coloured fluid injected into the subarachnoid space penetrates into the cochlea and vestibule.

The Bloodvessels of the Labyrinth.

The arteries of the labyrinth arise from the internal auditory artery (*arteria acustica centrala Sapolini*), which comes from the basilar, and enters the internal auditory canal along with the acoustic nerve. A small branch of this artery entering the vestibule supplies its lining membrane and the membranous semicircular canals, and sends small twigs to the utricle, saccule and ampullr, and an arch-shaped vessel along the concavity of the membranous semicircular canals. Another branch of the auditory artery (*ramus cochlearis*) sends twigs into the modiolus as the central arteries of the modiolus, and into the lamina spiralis ossea to the lining membrane of the cochlear wall. According to Böttcher (*A. f. O.*, vol xxiv.), only one vessel, known as the *vas spirale membranæ basilaris*, runs in the canalis spiralis of the cochlea, and supplies the ductus cochlearis with capillary branches. The subjective noises which are due to a disturbance in the circulation may, to a great extent, be attributed to this bloodvessel, which runs a long course on the lamina basilaris, and is in close relation with the nerve endings.
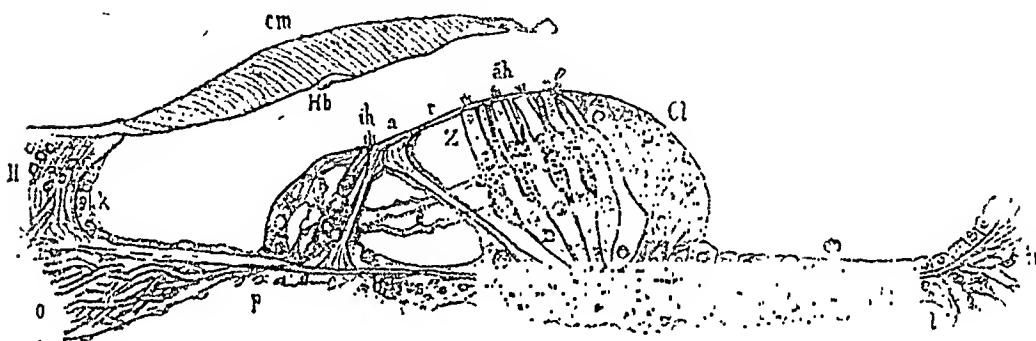
FIG. 77.—TERMINAL FILAMENTS OF THE COCHLEAR NERVE, WITH CORTI'S ORGAN, AS FOUND IN THE HUMAN SUBJECT.

o, Lamina spiralis ossea, with the nerve bundle of the ramus cochlearis; *pl*, Lamina spiralis membranacea; *H*, Tooth of Huschke (crista spiralis); *C*, Inner rods of Corti; *C'*, Outer rods of Corti; *r*, Lamina reticularis; *Z*, Corti's cells; *D*, Deiters' cells; *ih*, Inner hair-cells; *äh*, Four outer hair-cells; *e*, Radiating tunnel fibres of the ramus cochlearis passing to the cells of Corti; *k*, Cells of the sulcus spiralis interior; *Cl*, Hensen's supporting cells; *cm*, Corti's membrane; *vs*, Vas spirale; *tr*, Ligamentum spirale.

Siebenmann* distinguishes three main branches of the internal auditory artery in the labyrinth—the *arteria vestibularis anterior*, the *arteria vestibulo-cochlearis*, and the *arteria cochleæ propria*. According to this author, the blood returns also by three main channels—through the veins of the internal auditory canal, through the accessory canals of the aquæductus vestibuli, and through those of the aquæductus cochlearis.

O. Eichler† states that every turn of the cochlea has a separate blood-current, which is formed by the union of two adjoining currents—namely, that of the lamina spiralis and that of the walls of the scalæ. The very tortuous artery of each turn of the cochlea lies above Rosenthal's canal, and divides into two branches: the inferior runs to the vestibular surface of the

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* *Die Blutgefässe im Labyrinthe des menschlichen Ohres.* Wiesbaden, 1894.

† *Anatom. Untersuchungen über die Wege des Blutstromes im menschlichen Ohrlabyrinth (Abhandlungen der königl. sächs. Gesellsch. d. Wissenschaften*, vol. xviii., 1892).

lamina spiralis, while the superior ascends to the scala vestibuli, at the upper bend of which it runs to the outer wall of the cochlear canal. Both arteries form a capillary network from which the vein arises. This vein also consists of two branches, the superior of which runs on the lower wall of the lamina spiralis, the inferior on the floor of the scala tympani. Both branches unite into one vein in the modiolus below the canal of Rosenthal.

The Veins of the Labyrinth.—The veins of the vestibule and semi-circular canals empty into the vena aquæductus vestibuli, which runs in a separate bony channel and empties into the lateral sinus. The veins of the cochlea empty into the inferior petrosal sinus by means of the vena aquæ-ductus cochleæ, which runs in the canalis Cotunnii, below and parallel to the
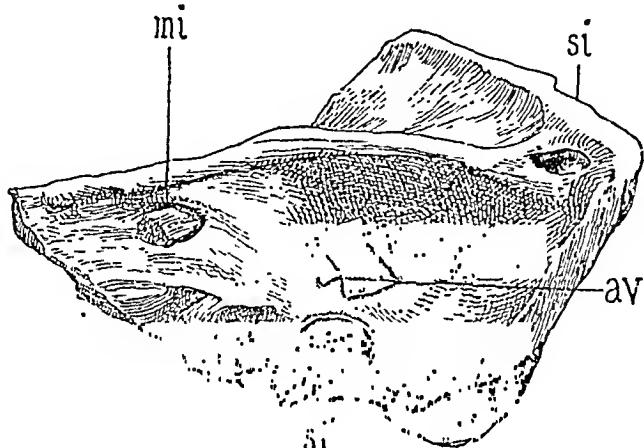
FIG. 78.—POSTERIOR SURFACE OF THE PYRAMID OF THE RIGHT TEMPORAL BONE OF AN ADULT, WITH THE OPENED INTRADURAL SAC OF THE AQUÆDUCTUS VESTIBULI.

mi, Internal auditory canal, with the acoustic nerve; *av*, Opened intradural sac of the aquæductus vestibuli; *si*, Upper section of the sigmoid sinus; *si'*, Its lower section. From a preparation in the author's collection.

aquæductus cochlearis (Siebenmann, *Injection der Knochencanäle*, 1899). The anastomoses of the vessels of the labyrinth with those of the tympanic cavity are brought about, as the author was the first to show (*vide* p. 37), by the vessels running in the external bony labyrinthine wall.

B. The Acoustic Nerve.

(a) The Origin of the Acoustic Nerve and its Distribution in the Labyrinth.

The acoustic nerve arises by two large nerve roots from the medulla oblongata between the facial and glosso-pharyngeal nerves; these roots unite into one nerve, which enters the internal auditory canal, in the fundus of which, it divides into two branches. The one branch, the vestibular nerve, enters the vestibule and sends several twigs to the utricle and the superior ampullæ of the semicircular canals; the other branch, the cochlear nerve, enters the modiolus of the cochlea and distributes small twigs to the saccule and to the ampulla of the superior (sagittal) semicircular canal (Rotzius). Numerous ganglion cells are found in the roots and trunk of the acoustic nerve.

Arnold describes two anastomoses between the acoustic nerve and the inter-medius nerve of Wrisberg (*nervo-tredicesimo*, Sapolini's). According to tho latest investigations of Penzo (*Att. istitut. Venet.*, 1890), these anastomoses are divided into a lateral and a medial ono. The medial consists of fibres which run from the intermedius nerve of Wrisberg to the vestibular branch of the acoustic nerve; the lateral, on tho other hand, is made up of fibres which go from tho intumescentia ganglioformis Scarpæ of the vestibular branch to the trunk of the facial nerve.

Alexander* distinguishes a superior and an inferior vestibular ganglion in man and higher animals. The superior belongs to the nervus utriculo-ampullaris. The greater part of the nervus saccularis and nervus ampullaris inferior ends in the inferior ganglion; still, a few twigs reach the superior ganglion by means of a channel, called by Alexander the *isthmus ganglionaris*.

The vestibular ganglion is united with the geniculate ganglion by a bundle of nerve fibres. Brühl and Bielschowsky (*Arch. f. mikro. Anat.*, vol. lxxi.) havo shown that there is a fibrillary network in the constant bipolar ganglion cells of the vestibular ganglion, in which tho thick central and thin peripheral process, which usually arises at opposite poles, passes over in a continuous manner. They found a similar network also in the cells of tho spiral ganglion.

According to Held,† an inconstant number of hair-cells of the ductus cochlearis is in connection with ono ganglion cell of tho spiral ganglion.

Ayers‡ found a great number of multipolar ganglion cells in addition to bipolar cells in the embryos of pigs, the sections of which had been stained by Golgi's chromic acid-silver method.

R. Krause § traced the acoustic nerve fibres into the terminal membranous apparatus by means of embryonic evolution, and found that there was an intimate union between the neuro-epithelial cells and nerve fibres, which took place 'during tho course of development. Recently Raymon y Cajal followed the branching of the vestibular nerves as far as the crista acustica, and found that the nerve fibres divide into small branches, which end in goblet- and cup-shaped processes.||

According to Kolmer,¶ the endings of the nerves of the macula and crista are supplied with nerves in a doubled manner. One thin nerve branches and ends in a button-shaped manner between the epithelial cells; the other thick nerve passes with its fibrilla direct and in a continuous manner into tho fibrillary network of the cells of special sense; the latter nerve lies in the protoplasm of the nerves of special sense. This fibrillary network develops in the embryo in the hair-cells below and around the nucleus, and changes its position in the fully-developed animal more to the surface of the cell and anastomoses with tho fibril of the opposite nerve. According to the investiga-tions of Brühl and Bielschowsky,** the non-medullary fibres of the nervus vestibuli terminate partly in free nodular endings between the hair-cells, and partly unite with the entire surface of the hair-cells and form within circular bodies in which probably the mechanism of transmission of the protoplasmic movement to tho norve fibrilla takes place.

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* *Zur Anatomie des Ganglion vestibulare der Säugetiere* (*Sitzungsber. d. kais. Akad. d. Wiss.*, vol. cviii., Abth. III., 1899).

† *Zur Kentniss der peripheren Gehörleitung* (*Arch. f. Anat. u. Physiologie*, 1897).

‡ *The Auditory or Hair-cells of the Ear and their Relations to the Auditory Nerve* (*Journal of Morphol.*, vol. iii., 1893).

§ *Die Endigungsweise des N. acusticus im Gehörorgane* (*Verhandl. d. anatom. Gesellsch. in Berlin*, Jena, 1896).

|| *Trabajos del lab. de Ins. Biol.*, Madrid, 1903, 1904.

¶ *Anatom. Anzieger*, vol. xxvi. and xxvii., 1905.

** *Loc. cit.*

The Distribution of the Acoustic Nerve in the Cochlea.

The fibres of the cochlear nerve pass through the openings of the tractus spiralis foraminulentus, part going directly to the first turn of the cochlea, and part passing into the nerve canals of the modiolus to the lamina spiralis ossea. Between the fibres of the modiolus and those of the lamina spiralis ossea there is found, at the periphery of the former, a large ganglionic layer (*zona ganglionaris*), which is enclosed by the sharply-defined oval canal of Rosenthal (Fig. 79). At the lower and medial sides of this canal the nerve bundles (*b, b', b''*) enter the ganglionic layer, and after numerous anastomoses with the ganglion cells at the upper part of the canal (*c*) pass into the lamina spiralis (*d*). The ganglion cells in the pike (Max Schulze) and guinea-pig are surrounded by medullary capsules.
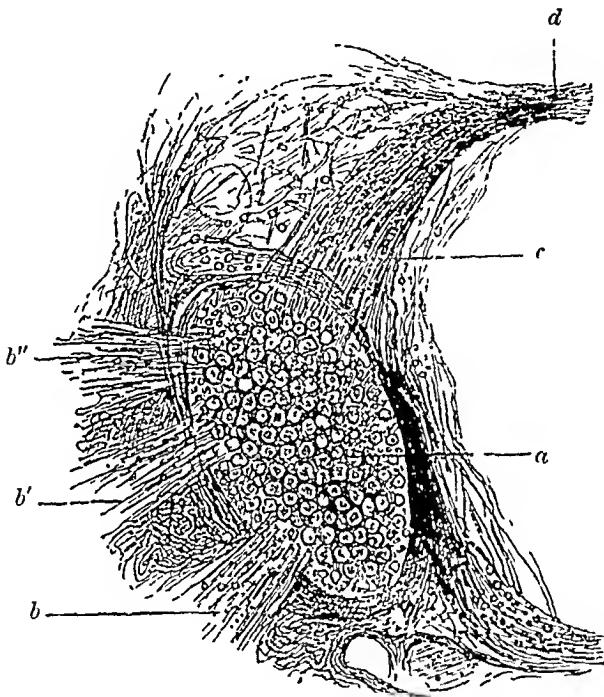
FIG. 79.—SECTION OF ROSENTHAL'S CANAL AND THE SPIRAL GANGLION.

a, Ganglion cells of the spiral ganglion lying in Rosenthal's canal; *b, b', b''*, Three separate nerve bundles of the cochlear branch entering the spiral ganglion; *c*, Nerve bundle coming from the superior pole of the spiral ganglion; *d*, Entrance of the latter into the lamina spiralis ossea. From a specimen in the author's collection.

The nerve fibres, which form plexuses by numerous transverse anastomoses, run between the two osseous lamellæ of the lamina spiralis, which are joined by vertical bridges as far as the *habenula perforativa* on the inferior surface of the basilar membrane. From here they pass through numerous openings on the upper surface of the membrane into the ductus cochlearis, and, according to the investigations of Waldeyer and Gottstein, enter into immediate union with the hair-cells as numerous non-medullated terminal fibres, which are very delicate and present nodes here and there. The researches of Retzius and Van Gehuchten show that the terminal filaments of the cochlear nerve form a fine network which surrounds the hair-cells, but does not enter into communication with them.

Brühl and Bielschowsky were able to demonstrate that the extreme terminal filaments of the cochlear nerve, form a nerve strand, which lies between Deiters' cells and is in direct communication with the floor of the hair-cells. The non-medullary terminal fibres of the spiral fibres (which run directly across Corti's canal) pass into this nerve strand, and form a fine fibrillary network. In the neighbourhood of the cochlea all the nerves of the latter type are in communication with the hair-cells.

FIG. 80.

(b) The Central Course of the Acoustic Nerve.

The Topographical Relations of the Acoustic Nerve and its Nucleus.

A section cut through the anterior third of the inferior part of the olivary body shows the origin of the acoustic nerve—that is, the ramus cochlearis (Fig. 80, *VIII* and *VIIIc*). In the main root of the acoustic nerve there can be seen, ventral to the corpus restiforme, the cochlear nucleus (nucleus accessorius acustici, Fig. 80, *NVIIIac*), which takes in the main mass of the fibres of the ramus cochlearis. A part of the latter unites with fibres which arise in the ventral cochlear nucleus, runs off in a lateral direction, and surrounds the corpus restiforme (Fig. 80, *VIIIc*) as a lateral acoustic nerve root. Dorsal to the corpus restiforme the fibres are interrupted in their course at the nucleus cochlearis dorsalis, the so-called tuberculum acusticum (Fig. 80, *TVIII*). The striæ acusticæ, which run along the floor of the fourth ventricle, must be looked upon as a continuation of this cochlear system: these run to the raphé, which they cross at different levels (Fig. 80, *Stra*). Close to the middle line the fibres slightly diverge and enclose the nucleus eminentiæ teretis.

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Ventral to these striæ, the floor of the fourth ventricle contains the small-celled triangular vestibular nucleus (nucleus vestibularis parvicellularis, Fig. 80, *Nvt*), lateral to which is attached the root of the spinal acoustic. It is divided into three parts: most medially the descending vestibular fibres (*VIIIav*); most laterally the connection of the medullary nucleus with the cerebellum (the tractus nucleo-cerebellares, Fig. 80, *Tnc*, which touches the restiform bodies); and lastly, between both, the large cells of Deiters' nucleus (nucleus vestibularis magno-cellularis, *Nmv*), with its own fibres.
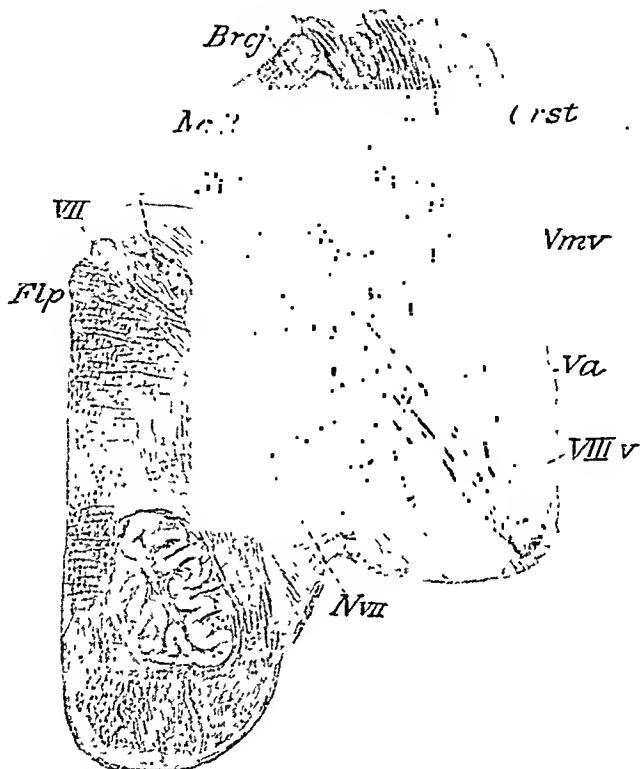
FIG. 81.

On a section made higher up the root of the ramus vestibularis (Fig. 81) may be seen in its entirety. This is due to the fact that the ventral part of the section lies more spinal than the dorsal. In such a section it is possible to see the main mass of the fibres running towards the small-celled triangular vestibular nucleus (*Nvt*), while a second part makes its way towards the large cells of Deiters' nucleus (nucleus vestibularis magno-cellularis). In the same channel with the fibres of the corpus restiforme (*Crst*), fibres come directly out of the vestibular and Deiters' nucleus in a dorsal direction. The former reach the small-celled nucleus angularis (Bechterew's nucleus, *NaB*), which lie medial to the brachium conjunctivum; the latter go into the cerebellum to the nucleus fastigii, the nucleus which is found on the roof of the fourth ventricle.

In consequence of the oblique direction of the sections, the other visible parts are not easy to recognize. There is also found a remnant of the facial nucleus (*NVII*), the fibres of which surround the nucleus of the abducens, and then form the ascending crus of the facial nerve, which lies in a direction dorsal to the fasciculus longitudinalis dorsalis (*Flp*).

The next section, at the beginning of the pons, shows the continuation of the acoustic fibres. The first structure which is seen is a bundle of fibres known as the tegmentum, which lies above the transverse fibres of the pons; they arise from the side of the ventral cochlear nucleus, surround the root of the spinal trigeminus in a ventral direction (Fig. 82, *Va*), and run in a bow-shaped manner towards the middle line, where they cross.

This bundle, which in animals lies, in the form of a short bridge, free on the surface, is the corpus trapezoides (Fig. 82, *Trs*). In its lateral third there is embedded a peculiar fibrous-like contorted structure, which is surrounded
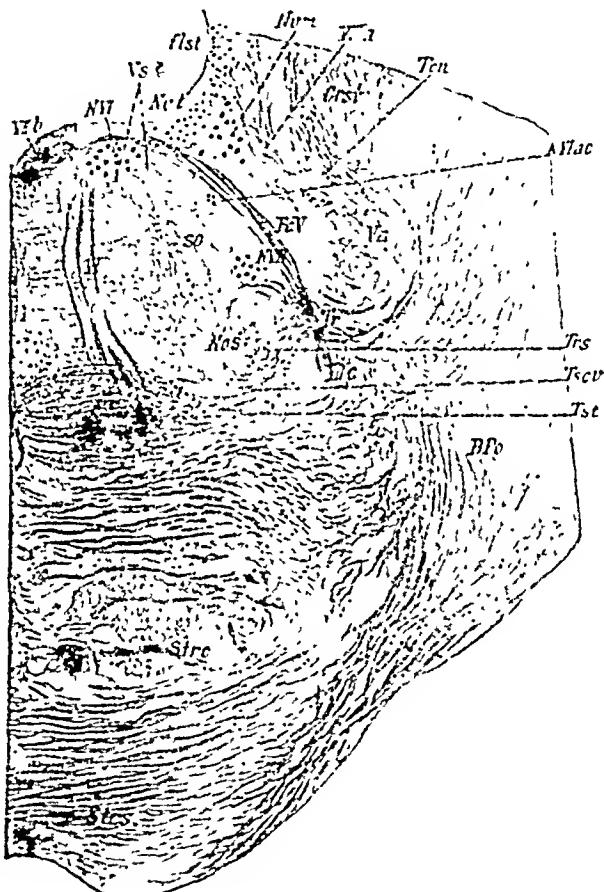
FIG. 82.

by gray masses forming a peculiar accumulation of cells—the superior olivary body (oliva superior, Fig. 82, *Nos*). From the corpus trapezoides radiating bundles go in a ventral direction into the olivary body; on the other hand, from the dorsal side the peduncular fibres sink into the olivary body (peduncles of the olivary body), which are regarded as a continuation of the striæ acusticæ (Fig. 82, *so*). Lateral to the olivary body, and at a higher plane, there is found a bundle which takes in the continuation of the corpus trapezoides, as well as the fibres of the olivary body, and is called the lemniscus lateralis. The cell-nests in the corpus trapezoides form the trapezoid nucleus. The superior olivary body is distinguished by its relation to the facial and abducens nerves. First it lies in a direction dorso-lateral to the facial nucleus (Fig. 82, *NVII*); laterally, it flanks the nerve where it emerges from the

brain (Fig. 82. *VIIc*), while the abducens, which lies medial to it, runs into the tegmentum (*VI*).

It must further be mentioned that also here there are remains of the small- and large-celled vestibular nucleus (*Nol*, *Nom*), and that the small cells which lie dorsal to Deiters' nucleus belong to the nucleus angularis (Bechterew's nucleus).[*]

The Origin and Central Prolongations of the Acoustic Nerve.

The acoustic nerve is divided into two parts, of which the one, the ramus cochlearis, has to do with the perception of hearing, while the ramus vestibularis is the principal factor in determining our position in space.

The ramus cochlearis has, like every sensory nerve, a peripheral ganglion, the ganglion spirale cochlearis (Fig. 83, *Gsp*), which contains also a few scattered cells lying in the nerve root. From this ganglion the fibres of the ventral and dorsal cochlear nucleus arise (accessory acoustic nucleus and tuberculum acusticum, Fig. 83, *NVIIIac*, *TVIII*). The latter is not so well developed in man as in animals. A few fibres are supposed to leave the ganglion above the two nuclei. In spite of many carefully conducted investigations, their course has not yet been fully demonstrated; up to the present only so much is known that the fibres which arise from the ventral cochlear nucleus pass through the tegmentum as the corpus trapezoides (Fig. 83, *Tr*), and, after they have decussated in the median line, form, to a large extent, the contralateral lemniscus lateralis (Fig. 83, *Ll*).

They give off direct as well as collateral fibres (radiating bundles) to the homo- and contralateral superior olivary body (Fig. 83, *Nos*).

Into the latter the prolongations from the tuberculum acusticum (Fig. 83, *TVIII*) also enter to a large extent; they then run along the floor of the fourth ventricle as the striæ acusticæ (Fig. 83, *Stra*), cross the median line, and form the peduncle of the superior olivary body (Fig. 83, *so*), by means of which they pass into the olivary body itself. Other fibres of the striæ cross deeper and are called the striæ profundæ (Fig. 83, *Strap*). A part of the striæ fibres remain homolateral and join the corpus trapezoides. It is not an interealary ganglion which carries the acoustic irritation to the nucleus of the orbital muscles, the spinal cord, etc., but an acoustic nucleus of a higher type, the larger part of which is perhaps identical with the substantia gelatinosa of the posterior horns of the spinal cord (Hoffmann). The cells of the olivary body supply a large part of the fibres of the lateral lemniscus (Fig. 83, *Le*), which finally contains the entire continuation of the ramus cochlearis; also the fibres of the lateral lemniscus are interrupted in their course at the ventral and also at the dorsal lemniscus nucleus (Fig. 83, *NLlv* and *NLld*). Finally, the main mass of the fibres extend to the corpora quadrigemina posterior (Fig. 83, *Cqp*) and from here (after they are again interrupted in their course) enter into the brachium of these bodies (*Brcqp*), through which they pass into the ganglion geniculatum mediale (Fig. 83, *Cgl*). After they have passed into the pons, like all other sensory nerves, they are again interrupted in their course by the cells of the corpora geniculata; from here the auditory radiations, which lie in the retrolenticular part of the internal capsule, pass to the cortex of the temporal lobe (Fig. 83, *Ct*, most probably to the first temporal lobe, gyrus transversus, Heschel's lobe). Inasmuch as each temporal lobe is supplied by both rami cochleares, disturbances in hearing of a high degree are not induced by diseases of the cortex. The same is true of affections of the posterior corpora quadrigemina (Siebenmann); on the other hand, affections of the corpora geniculata, of the brachia of the posterior corpora quadrigemina,

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[*] Description and plates according to Marburg, *Mikroskopisch-topographischen Atlas des menschlichen Zentralnervensystems*, Deuticke, Wien-Leipzig, 1904.

and also of the lemniscus lateralis, produce disturbances of hearing, although they do not reach a high degree.

The relations of the ramus vestibularis are not so complicated; it has its peripheral ganglion in the ganglion vestibuli (Fig. 83, *Gv*), and runs from
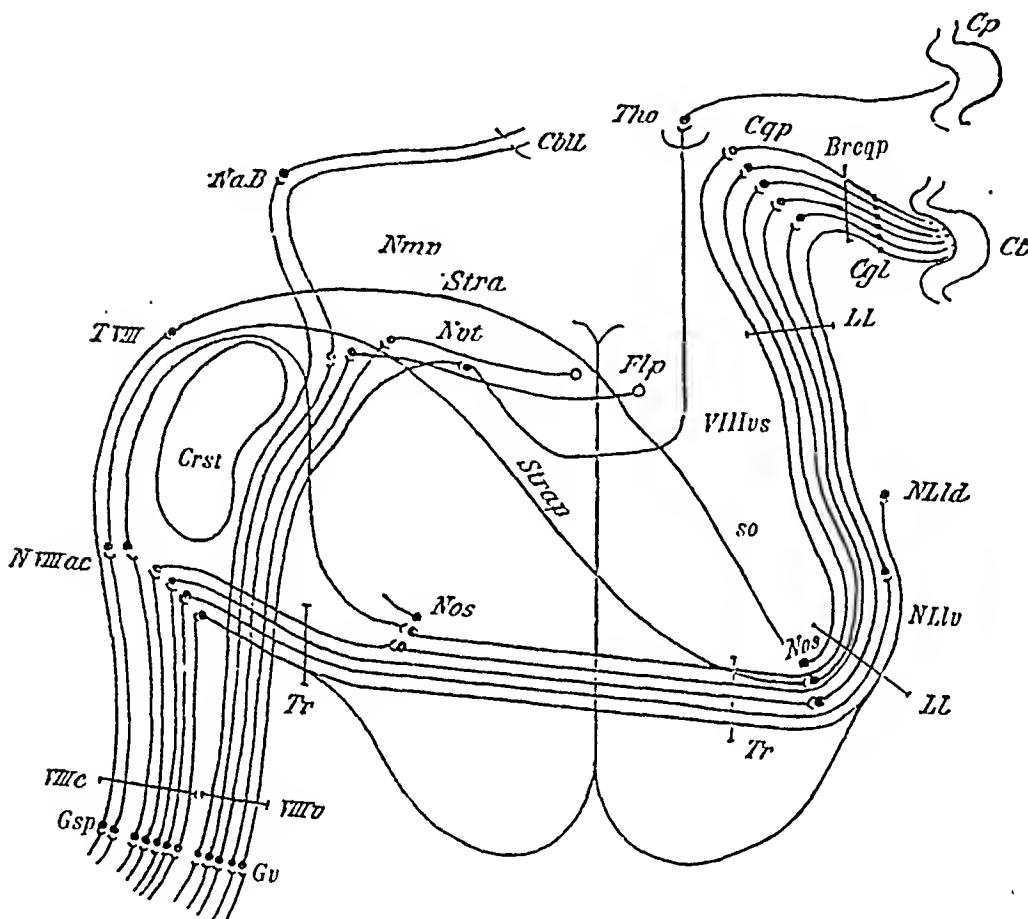
FIG. 83.

Brcqp, Brachium corp. quad. post.; *Cbll*, Cerebellum; *Cgl*, Ganglion geniculatum mediale; *Crst*, Corpus restiforme; *Cqp*, Corpus quadrigeminum posterior; *Ct*, Cortex (first temporal lobe); *Flp*, Fasciculus longitudinalis posterior; *Gsp*, Ganglion spirale cochleæ; *Gv*, Ganglion vestibuli; *Ll*, Lemniscus lateralis; *NaB*, Nucleus angularis Bechterew; *Nmv*, Nucleus magno-cellularis vestibularis (Deiters' nucleus); *NLld*, Nucleus lemnisci lateralis dorsalis; *NLlv*, Nucleus lemnisci lateralis ventralis; *Nos*, Oliva superior; *Nvt*, Nucleus vestibularis triangularis; *NVIIIac*, Nucleus acustici accessorius (N. coch. vent.); *Stra*, Striæ acusticæ superficiales; *Strap*, Striæ acusticæ profundæ; *so*, Peduncle of superior olivary body; *Tho*, Thalamus opticus; *Tr*, Corpus trapezoides; *TVIII*, Tuberculum acusticum; *VIIIc*, Ramus cochlearis acustici; *VIIIv*, Ramus vestibularis acustici; *VIIIvs*, Secondary course of the ramus vestibularis (Obersteiner).

there into the medulla oblongata on a cerebral plane with the ramus cochlearis medial from the corpus restiforme (Fig. 83, *Crst*). In the medulla it divides into ascending and descending branches, the latter of which form the medial part of the root of the spinal acoustic; they then descend to the region of the hypoglossus. They end in the small-celled vestibular nucleus (nucleus

triangularis, or parvicellularis vestibularis, Fig. 83, *Nvt*), and its continuation, which can be traced to the hypoglossus, is known as the descending vestibular nucleus and nucleus intercalatus Stadernii. Direct continuations or collateral branches of the ramus vestibularis also approach Deiters' and Bechterew's nucleus (nucleus vestibularis magno-cellularis and nucleus angularis, Fig. 83, *Nmv* and *NaB*). Still Deiters' nucleus is now looked upon more as an independent structure—a nucleus of co-ordination (Kohnstamm). Its relation, on the one hand, to the cerebellum and the vestibular nerve, and, on the other, to the nerves of the muscles of the eye and to the cervical muscles (posterior longitudinal fibres, fasciculus longitudinalis, Fig. 83, *Flp*) explain clearly the important rôle it plays in determining our position in space and in the production of nystagmus (Spitzer and others).

In regard to the central tracts, which run from the region of the vestibularis to the cerebellum, it is only known that they run through the substantia reticularis of the tegmentum into the thalamus (Fig. 83, *Tho*), and from here—after the fibres have been interrupted in their course—to the cortex, where they are supposed to end in the posterior part of the parietal lobe (Fig. 83, *Cp*), which also aids in determining our position in space.

The Physiology of the Internal Ear.

It has already been said that the conduction of the waves of sound from the membrana tympani to the labyrinth is principally brought about by the foot-plate of the stapes (p. 55). The sound-waves transmitted simultaneously from the membrana tympani to the membrane of the round window are of less physiological importance.

Only a minimum amount of displacement of the aqua Cotunnii is brought about by transmission of the waves of sound to the labyrinthine fluid. Burnett and Buck have shown experimentally that this displacement is much greater for deep tones than for high ones, and that the latter cause hardly any appreciable movement of the labyrinthine fluid.

Corresponding to the inward motion of the foot-plate of the stapes during the positive phase of the waves of sound, the fluid of the labyrinth is principally displaced towards the round window. The membrana basilaris of the cochlea is thus somewhat bulged towards the scala tympani and made tense owing to the resistance of the apex of the cochlea (Helmholtz). Hensen thinks that the fluid also enters both aqueducts of the labyrinth simultaneously, but according to the opinion of the author this is hardly possible on account of the extreme narrowness of the aqueducts and the strong resistance in the cranial cavity.

The functions of the different parts of the labyrinth have not yet been fully explained; still, great progress has been made in this direction through the works of Helmholtz, Hensen, Ranke, Hasse, Exner, and others.[*]

The Function of the Vestibular Apparatus.—It was formerly believed that the function of the saccule and utricle was mainly to aid in the perception for noises, and that the cochlear apparatus served for the perception for tones. This view has now been renounced. According to the current opinion, the function of the vestibular apparatus is to inform us of the motions of the head, and consequently of the body in space; that is to say, in apprising us of the relative position of the head (body) to the line of gravity, thus enabling us to keep the body in its equilibrium. With every forward movement and with each inclination of the head the relatively heavy otoliths remain in the medium in which they are suspended, thereby causing a bending of the delicate hairs which support them; this bending produces

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[*] Stanislaus v. Stein, *Die Lehren von den Functionen der einzelnen Teile des Ohrlabyrinthes*, Moskau, 1892. 840 pages in the Russian language. German by Dr. v. Krzywicki, 1894.

specific sensations, which become apparent by means of numerous nerves (Brener).

As the directions in which these otoliths can move also correspond to the three dimensions of space, combination of these is sufficient for every case.

The Function of the Semicircular Canals:—It was formerly believed that the solid angle, which is formed by the perpendicular arrangement of the semicircular canals to each other, imparted to the ear the power of locating the direction of the waves of sound.   We now know that these canals take no part in the perception for sound, but are the organ of co-ordinated movements (statical sense).

The fundamental experiment upon which this latter view is based was performed by Flourens. He noticed a striking motor disturbance after section of the semicircular canals in pigeons and rabbits, which led him to believe that these canals were the central organ of co-ordinated movements. It was especially noticed from his experiments, as well as from those carried out later by others, that a lateral movement of the head combined with nystagmus and vomiting (Czermak), and a rotation of the body on its vertical axis, took place after section of the horizontal semicircular canal: that a pendulous movement of the head forwards and backwards, and a falling of the body backwards, followed destruction of the sagittal semicircular canal; and, finally, that the animal fell forwards when the superior semicircular canal was injured.

The views regarding the significance of the symptoms after destruction of the semicircular canals vary considerably in spite of numerous control experiments.

Goltz, Mach, Czermak, Curschmann, Spamer, Brener, Crum-Brown, Bechterew, Ewald, and König, consider the semicircular canals as the sense-organ for maintaining the equilibrium of the body. Cyon looks upon them as the organ of the sense of space. The symptoms brought about by the experiments of Flourens are regarded by all these investigators as the result of the destruction—that is, irritation—of the semicircular canals and ampullæ. Breuer (*Pflüger's Archiv*, 1888) has shown that, by carefully opening one of the semicircular canals in pigeons, a chemical or thermic irritation, or simply touching the said canal, is sufficient to bring about a disturbance in equilibrium.[*]

Högyes (*Pflüger's Arch.*, vol. xxxvi.) believes that the vestibular endings of the auditory nerve are peculiar terminal apparatus which, according to the position of the head and body, regulate the movements of the eyes, and probably also those of the most important muscles of the body necessary to maintain the equilibrium.   This view is supported by the experimental investigations of Cyon (*Recherches sur les fonctions des canaux semicirculaires*, Paris, 1878), who observed movements of the eyes in certain fixed directions after injuring the different semicircular canals.

The statements of Lussana, that the disturbances of co-ordination which arise in consequence of injury to the semicircular canals are caused by irritation and not by destruction of the nerves of the ampullæ, have been proved to be incorrect by the experiments carried out by König (*Études expérimentales des canaux semicirculaires*, Thèse, Paris, 1897) on animals. This author found that after anæsthetizing the canals with cocaine, the well-known disturbances of equilibrium nevertheless appeared, showing that these must be regarded, not as symptoms of irritation, but as signs of non-activity of the semicircular canals; this view is also shared by Gaglio (*Arch. p. l. scienze med.*, vol. xxiii., 1899).

Brown-Séquard, Cyon and Bechterew also observed rotatory and rolling movements of the eyes and bilateral nystagmus after section of the acoustic nerve, while Biehl noticed the same after division of the vestibular branch.

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* See L. W. Stern, *Die Literatur der nicht acust. Functionen des inneren Ohres bis zum Jahre* 1895 (*A. f. O.*, vol. xxxix., 1895).

R. Ewald,* who bases his results on experiments carried out on animals, differentiates two parts of the labyrinth, the ' hearing labyrinth ' and the ' muscular-tone labyrinth,' of which the latter is divided into (*a*) Goltz's sense organ (semicircular canal apparatus), and (*b*) the maculæ acusticæ (otolith apparatus). According to Ewald, the muscular-tone labyrinth influences not only the muscles of the entire head and movements of the eyes, but also the muscles of the body. It has been found in animals that an abnormal atony of the limbs develops after removal of the labyrinth, and that a general atrophy of the muscles ensues after plugging the semicircular canals. This theory has been supported by the later examinations of Asch, Dreyfuss, Willgerodt, Bethe, and Fröhlich (*Pflüger's Arch.*, vol. cii.), who observed in lower animals a falling off of the motor force, with a simultaneous increase of the reflexes.

According to the present hypothesis, the adequate irritation of the cristæ acusticæ of the ampullæ is supposed to be brought about by the currents of the endolymph, and that every change in the position of the otoliths has, as a consequence, the sensation of a change in the position of the head in an opposite direction to their motion. Hence the function of the semicircular canals is believed to be the perception for the rotations of the head, and by this means of the body, in the form of angular accelerations. With each turn of the body the endolymph, owing to its momentum of inertia, makes a relative movement towards the walls of the canals, whereby it necessarily happens that a bending of the fine hairs which are firmly connected with the walls of the semicircular canals, and which belong to the nerve apparatus of the ampullæ, is brought about. At the commencement of a motion, the hairs bend in an opposite direction to that of the motion, but (the above fact taken for granted) is correctly perceived. This produces a nystagmus which has the same direction as that of the turning. If the motion lasts only a short time, the otoliths return to their normal position when the turning ceases, and the revolving sensation and the nystagmus cease. If the turning lasts a longer time, the hairs of the otoliths, in consequence of their elasticity, return slowly to their normal position, and the revolving sensation and nystagmus cease, but again immediately return if the same motion is continued faster. When the revolutions become slower (which may be termed negative slowness), or when they are made to cease, the endolymph, owing to the slowing down, keeps on flowing in the direction of the motion and causes a corresponding change in the position of the otoliths. This brings about the feeling of being turned in the opposite direction and also nystagmus to the side opposite to that of the turning. If this bending is transposed into nerve irritation, the three semicircular canals, which are cognizant of the three dimensions of space, cause sensations by their combinations, which, according to the strength and distribution to the three nerve endings, are characteristic for the rotation in every axis.

Further experiments show that reflexes also originate from the semicircular canals, by which the position of the head and eyes is altered as occasion requires. Nystagmus is the most striking and practically the most important of these reflexes. It may be produced by various methods of irritating the labyrinth, most clearly by turning or by galvanic or caloric irritation.

1. *Rotatory Nystagmus.*—It always occurs in a plane through one or both bulbi oculi, which is at right angles to the axis of turning. Its fast component is always in the direction of the rotation. If the patient looks in the direction of the fast component the nystagmus is increased; if, on the other hand, the patient looks in the direction of the slow component, the nystagmus becomes less marked or ceases entirely. If the patient is subjected to more than eight revolutions in one direction, the nystagmus, during the procedure, stops. When the turning stops, the nystagmus goes to the opposite side. Associated

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* *Physiolojische Untersuchungen über das Endorgan des Nervus octavus,* 1892.

with this form of nystagmus are a number of accompanying symptoms. These are: objects appear to revolve in the direction of the fast component; a feeling of rotation of the entire body in an opposite direction; a darkening of the field of vision; the sensation of seeing colours; nausea; and vomiting. These partly objective and partly subjective phenomena are grouped together and are called rotatory giddiness.

2. *Caloric Nystagmus.*—Dr. Barany observed at the author's clinic that nystagmus can be produced to the opposite side when syringing the ear with cold water (below the bodily temperature), and to the same side when syringing with hot water (above the bodily temperature). According to Dr. Barany's investigations, this nystagmus is not caused by pressure, but solely by the flow of the endolymph, caused by a difference in temperature between the injected fluid and the warmth of the body. Water having the same temperature as that of the body causes no nystagmus. Naturally cold and warm water work the faster, the greater their difference as compared with the bodily temperature. They also act quicker when the membrana tympani is perforated than when it is intact.*

3. *Galvanic Nystagmus.*—When a galvanic current of 2 to 4 milliampères is allowed to pass straight through the head, nystagmus is produced, which must be attributed to an irritation of both labyrinths. If, on the other hand, only one labyrinth is irritated, in that the cathode is placed in front of the tragus and the anode on any spot on the same side of the body (for example, the hand), nystagmus towards the cathode is produced. If the anode is placed before the tragus and the cathode is taken in the hand of the same side, nystagmus occurs to the opposite side—that is, away from the anode In conducting these experiments a current of 10 to 15 milliampères is used.

The importance of these methods of irritating the vestibular apparatus for clinical purposes, as well as their use in the pathology of labyrinthine—and brain—diseases, will be spoken of more fully later.

The experiments of Kreidl† performed on deaf-mutes give us important data regarding this question. He found, in the majority of cases of accelerated rotation, that the characteristic normal movements of the eyes were absent. A number became confused as to the vertical line, a condition which is met with in normal individuals during rotation. The statements of Kreidl are corroborated by Bruck. In 30 per cent. of the individuals experimented upon by Kreidl, J. Pollak‡ showed that the so-called 'galvanic dizziness' was wanting.

Recent investigations by Wanner, Hammerschlag, Frey, and Barany on deaf-mutes, and the very carefully conducted experiments of Kreidl and Alexander on the Japanese dance mouse, have brought forth new proof of the already accepted theory that giddiness, nystagmus, and disturbances in gait may be produced from the labyrinth. Frey (*Verhandl. der Deutsch. otolog. Gesellschaft*, 1904) found in a large percentage of deaf-mutes a diminution of the patellar reflex, especially in those cases in which, upon turning, giddiness and nystagmus could not be produced.

The Function of the Cochlea.—Our present knowledge is entirely hypothetical in reference to the function of the cochlea, and the different parts of this complicated terminal apparatus. Helmholtz was of the opinion that the cochlea possessed a greater physiological function than the vestibule and semicircular canals, and that it served the purpose of analyzing the waves of sound. It has not yet been shown what part of Corti's organ corresponds functionally to the layer of rods and cones of the retina. The old view of Helmholtz, that Corti's rods should be considered the terminal apparatus of

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* Confirmed by Kubo by experiments on animals under the supervision of Kreidl (*Arch. f. d. Ges. Physiol.*, vols. cxiv. and cxv.).

† *Pflüger's Arch.*, vol. li., and *Sitzungsber. d. Wien. Akad. d. Natur. wiss.* (Class C, i. 3; as well as C, xi. 3).

‡ *Pflüger's Arch.*, vol. liv.

the auditory nerve, had been abandoned by this author himself, since objections had been raised against this theory which demonstrated that it was unsound. Hasse found that Corti's rods are absent in birds which possess a hearing power for musical tones and speech, and that, on the other hand, Corti's cells are present.* These cells, which have small auditory cilia at their upper ends (outer and inner hair-cells), are, according to Waldeyer, about 2,000 in number, and are now universally regarded as the true terminal apparatus of the cochlea. Corradi (*A. f. O.*, vol. xxxii.) observed total deafness follow the destruction of the cochlea in dogs, and is therefore of the opinion that the cochlea is the only organ for the reception of the acoustic impressions.

Helmholtz later agreed with Henson that the basilar membrane is that part of the cochlea which is attuned to the sounds of the external world, and from which the vibrations of the labyrinthine fluid are transmitted to Corti's cells. Henson based this opinion on the fact established by Hasse and himself that the basilar membrane is not equally wide at all its parts, but increases in width as it ascends from the first turn of the cochlea towards the cupola. According to Helmholtz, the basilar membrane represents a system of strings corresponding to its striæ, of which only a fixed number always vibrates for certain tones. Accordingly, therefore, the perception for high tones is brought about by the lower part of the basilar membrane, and that for deep tones by its upper portion. The covibration of one group of fibres must not, however, be regarded as isolated and sharply defined. It is much more probable, according to Helmholtz, that the perception does not take place in interrupted succession, with increasing tones, but in a continuous rise, and that when one group of fibres is set into vibration the neighbouring one is also similarly affected to a slight degree.

Helmholtz's theory of sound analysis is based on the assumption that the basilar membrane of the cochlea possesses a large number of so-called sounding-boards (resonators), which are tuned to certain tones. These sounding boards are set into action by the vibrations conducted by the aqua Cotunnii; these vibrations are transmitted to our brain as impressions of sound by the nerve fibres corresponding to these sounding-boards.

According to Herrmann (*Arch. f. d. ges. Physiologie*, vol. lvi., 1894), each sounding-board (resonator) in the cochlea is not put into action by its acoustic fibre, but by aid of a nerve cell which has an elective irritability for each rhythmical irritation. Ebbinghaus is of the opinion that each fibre of the basilar membrane is not only able to give rise to its keynote, but also to bring about a diminished perception for the overtones owing to the formation of nodes.

Of the many theories, Ewald's† also deserves to be mentioned. He thinks that with every tone the entire basilar membrane vibrates. The vibrations, he thinks, take place in a perpendicular wave-like manner, which, in its entirety, produces a so-called characteristic sound-picture for every tone. According to the theories of Max Mayer‡ and ter Kuile,§ the entire membrane does not vibrate, but only a part of it. According to Mayer, the height of the tone is determined by the number of concussions, which puts into action a sensory cell.

Ter Kuile is of opinion that it is the period only that causes certain cells to be put into action by a fixed tone (compare J. Breuer, *Uber das Gehörorgan der Vögel, Sitzungsbericht d. Kais. Akad. d. Wiss. in Wien.*, 1907). Kishi

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* Denker found that the power which the parrot possesses of reproducing the speech is not due to any special structure in the sound-perceiving apparatus.

† *Pflüger's Arch.*, 1899, 1903.

‡ *Zeit. f. Physiol.* and *Psych. d. Sinnesorg.*, vol. xvi.; *Pflüger's Arch.*, 1899, 1900.

§ *Pflüger's Arch.*, vol. lxxix.

(*Pflüger's Arch.*, 1907) believes that the vibrations commence in Corti's membrane, and are carried over from here to Corti's organ.

With the aid of the shifting of the tone phases, recent investigations (Exner, Pollak,* Hensen†) have strengthened the belief in the resonance theory in opposition to that of the Helmholtz theory, which cannot be made to harmonize in reference to the perception for combination tones and interference sounds, as well as for the shifting of the tone phases and the occurrence of tone-gaps (Meyer-Stumpfs, *Beitrage zur Akustik*, etc., 1898). According to Bezold,‡ the occurrence of tone-gaps may also be explained by the Helmholtz theory. Up to the present the occurrence and perception of combination tones has not been explained. Helmholtz and Schäfer§ regard the membrana tympani and the ossicles as the place of origin for combination tones. In opposition to this, Dennert‖ says that individuals in whom the membrana tympani, the malleus, and the incus are lacking, can hear combination tones. Wundt¶ claims that the perception for combination tones is due to irritations brought about by the meeting of two fundamental tones within one and the same nerve fibre.

Exner has shown experimentally that the perception for noises is also brought about by the cochlea.

According to Ewald, the root of the acoustic nerve is also susceptible to sound impressions; this view is shared by Wundt,** while Bernstein,†† Matto, and Strehl‡‡ hold an opposite opinion. Kuttner§§ found that pigeons without labyrinths react especially well to deep tones, but thinks that the reaction is probably caused by means of the sensory nerves. Kroidl and Janase (*Centralbl. f. Phys.*, vol. xxi.) found that the confused manner in which some animals hear during the first few days of life is due to the fact that Corti's organ is not yet fully developed, and that as soon as Corti's membrane is set free from Corti's organ the perception for sound takes place.

A few physiological peculiarities of the acoustic apparatus must finally be mentioned.

After-perceptions in the ear may be produced by noises as well as by tones; by this we mean that the perception for a tone lasts a short time after the action of the objective source of sound. Preyer informs us of peculiar after-perceptions which are experienced after the long-continued action of a tone, and especially of the distinct perception of vibrations which continue for some time after. Fechner considers the after-perceptions as mental pictures, while Urbantschitsch calls them positive after-images analogous to those of the eyes. If we accept this view that we are dealing with positive after-images, the fact still remains unexplained why they are observed only in a very small number of individuals in whom the ears are normal.

The energy of perception of the auditory nerve is, as Dove first proved, diminished even after a short action of sound, and, as he expresses it, the ear becomes fatigued. Urbantschitsch found, in his experiments in reference to this subject, that the diminution in perception takes place mainly for that tone or group of tones conducted to the ear, but that other tones immediately thereafter will be perceived with undiminished intensity.

If a tone is conducted simultaneously to both ears by means of a tube with two branches, the perception (acoustic image) will be localized, according to

* *Zeitschr. f. Psych. u. Physiol. d. Sinnesorg.*, vol. xxxii.
† *Bericht. d. Berliner Akad. d. Wissensch.*, 1902.
‡ *Münchener med. Woch.*, 1900.
§ Nagel's *Handbuch d. Physiol.*, p. 569.
‖ *A. f. O.*, vol. xxiv.
¶ *Philosophische Studien*, vol. viii.
** *Ibid.*, 1893, vol. viii., and *Pflüger's Arch.*, vol. lxi., p. 339.
†† *Pflüger's Arch.*, vol. lxi., p. 113.
‡‡ *Ibid.*, vol. lxi., p. 205.
§§ *Ibid.*, vol. lxiv., p. 249.

Elliot,* Purkinje, and Thompson, in the centre of the occiput. Later experiments do not agree with this statement, in so far as Plumendon considers the frontal region as the place of perception. Urbantschitsch has applied the term ' subjective field of hearing ' to this perception.

The statement of Urbantschitsch, that increased perception in individuals with binaural, over those with monaural, hearing is brought about by the transmission of the subjective irritations from the acoustic centre of one side to that of the other, seems unfounded, as a simple explanation for this phenomenon is found in the well-known physiological law of the summation of sensitive irritations.

The phenomenon observed by Le Roux that the action of the waves of sound on one ear (tuning-fork) heightens the power of perception in the other, has been verified by the investigations of Urbantschitsch. According to the opinion of the author, this applies only to certain kinds of tones and noises (as, for instance, the tick of a watch, etc.), as the perception for a weak-sounding tuning-fork in one ear is completely destroyed by the action of a stronger sounding one in the other ear. This, therefore, refutes the above theory that the perception is increased in binaural hearing. The phenomenon described by Chabalier, Lussana, Nussbaumer, Padrono, Grazzi, Cozzolino, Baratoux,†-Lehmann, Bleuler, and others, in which peculiar sensations of colour are brought about by the action of the waves of sound (sound photisms), must be regarded as rare reflex sensations arising from the ear. From a hypothesis advanced by Steinbrügge, this double sensation can be explained by the fact that the acoustic irritation does not confine itself to the hearing centre in the cortical portion of the brain alone, but passes beyond the border and reaches the centre of sight by means of fibres of association.‡

It is also known that a reflex action of all the muscles of the body may be produced by irritation of the acoustic nerve, a fact which is shown by the sudden drawing together of the entire body owing to a loud, unexpected sound, etc. Högyes observed in new-born rabbits that every time a tuning-fork was struck a quick motion of the auricles took place from behind forwards. Moldenhauer could produce muscular reflexes which extended over a part of or over the entire body of the new-born by varying the intensity of the sound employed. Repeated observations have shown that dizziness, spasms of the respiratory muscles (Kosegarten), and an accelerated or slowed action of the heart (Dogiel, *Arch. f. Anat. u. Phys.*, 1880) could be produced by musical tones, or by certain kinds of noises and sounds.

During the last few years special interest has been paid to the so-called cortical centre of hearing, both from a physiological and from a clinical point of view. The existence of such a centre has been firmly established by numerous experiments on animals (Munk, Ferrier, Luciani, Yeo, Horsley, Singer, Brown, Tamburini, Goltz, Schäfer, and others) and by anatomical and clinical observations (Flechsig, Bechterew, Monakow, Baginsky, Forel-Onufrowicz, Roller, Oseretzowsky, Kramer, Held, Kölliker, and others). The statements vary greatly, however, as to the exact location of this cortical centre of hearing. Some investigators think that it is situated in the posterior portion of the first, or in the posterior two-thirds of the first and second temporal convolutions; Luciani found, however, that the cortical hearing centre extends far

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* Cp. Politzer, *Gesch. der Ohrenheilk.*, vol. i., p. 295.

† Cp. Baratoux, *L'audition colorée.* Paris, 1888.

‡ Cp. Binet, *Revue des deux Mondes*, 1892.

beyond this limit in an anterior and posterior direction. Goltz even discovered in dogs that no deafness resulted after the complete removal of both cerebral hemispheres. Alt and Biehl found that after the extirpation of one temporal lobe both organs of hearing were affected—the collateral one in a higher degree. It could not be determined which of the temporal lobes was of greater import-ance—that is, as far as the hearing region is concerned. After the removal of both temporal lobes complete deafness set in, which lasted ten to twelve days; after this there occurred a slow reaction to sound, which gradually increased.

Rawitz (*Morpholog. Arbeiten*, vol. vi., 1896) found the right temporal lobe one-half, the left one-third, its original size, in a dog with blue eyes' which was congenitally deaf. According to this author, this proves the statements of Munk. On the other hand, Alexander (*Centralbl. f. Physio-logie*, 1899, vol. xviii.) found in a deaf albino cat retrogressive changes in the cochlea and in the auditory nerve, but no abnormal changes in the tem-poral lobes. Kalischer (*Preuss. Akad. d. Wissenschaft*, 1907) found in dogs which were trained to fixed tones (noises made by the mouth) that total deaf-ness for all tones was produced only through bilateral destruction of the posterior corpora quadrigemina. Rottmann—who confirms in general the experiments of Kalischer—found that after a long time the perception for weak sounds returned to the animals, and that only after destruction of the corpora geniculata media the dogs remained absolutely deaf (*Vers. deutsch. Naturf. u. Ärzte.*, Dresden, 1907).

THE METHODS OF PHYSICAL EXAMINATION OF THE ORGAN OF HEARING.

A. The Examination of the External Auditory Canal and Tympanic Membrane.

Examination of the external auditory canal and of the tympanic membrane is indispensable for the diagnosis of diseases of the ear. The membrana tympani is, in consequence of its anatomical position, in intimate relation with affections of the auditory canal and of the middle ear. The processes of disease in these parts cause changes in the membrana tympani which may be recognized by inspection, and enable one to draw conclusions as to the pathological state of the external and middle ear; as experience shows that diseases of the tympanic cavity most frequently form the basis of a disturbance of hearing, and are very often combined with changes on the membrana tympani, it can be seen that the condition of the latter is of great importance in the diagnosis of affections of the middle ear.

In judging the pathological changes on the drum membrane, it must, however, be mentioned that in quite a few persons with normal hearing congenital or acquired changes are observed which do not cause the least disturbance in hearing. On the other hand, however, in a considerable number of patients with a deafness of a high degree not the least change is found on the membrane.

The pathological changes on the drum do not allow us in every case to come to a conclusion as to the degree of the disturbance of hearing. We will see that not infrequently extensive perforations, cicatrices, and chalk deposits are accompanied by only a slight degree of deafness; while, on the other hand, with slight deviations from the normal condition of the membrane, a high degree of deafness is often observed.

It will be noted in a special chapter on middle-ear affections that those products of disease are most important which produce pathological changes at the labyrinthine windows and bring about a disturbance of hearing by diminishing the mobility and power of vibration of the ossicles.

The most practical method of inspection, and the one universally used, is the examination with the solid funnel-shaped speculum and the concave head mirror used as a reflector, or we may obtain good illumination from an electric head light, the current of which is obtained from a small dry-celled pocket battery. Another practical instrument for aural examinations, and one extensively used, is the electric auriscope, with its small electric bulb, which receives its current from a small dry cell within its handle. This is particularly useful for bedside examinations and in such places where indirect illumination is impossible. The small magnifying lens at the outer larger opening affords a magnified image of the drum and adjacent structures, so that one is more readily able to recognize the most minute pathological changes.

Specula.—The solid funnel-shaped specula first introduced by Deleau and Ignaz Gruber, and somewhat modified in shape and size by Arlt, Toynbee, Wilde (Fig. 84), Ehrhard (Fig. 85), and Boucheron, consist of metal with a polished or blackened interior. They are either funnel-shaped or like a truncated cone, and possess a round, oval, or oblique aperture at their extremity; their dissimilarity as well as their shape is of little importance in the examination of the ear.

The vulcanite specula (Fig. 86) which the author introduced into practice have the advantage of being considerably lighter, whereby they remain in the required position better than the heavy metal ones. The black interior allows the membrane to be more clearly seen than the polished interior of the metallic specula, as they do not have the annoying light-reflex.

The smaller openings of these specula are of four different sizes – namely, 2, 4, 6, and 8 mm.—and are thereby made to suit the individual variations in the size of the external meatus.

Technic of Otoscopy.—The head of the patient, who is seated, must be so placed during the examination that the ear to be examined is turned away from the light, and the latter so adjusted that the rays which fall on the concave head mirror are reflected directly into the meatus.

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In order to insert the speculum into the external auditory canal, the auricle must be drawn backwards, upwards, and somewhat towards the observer, with the left index and middle fingers. We do this in order to bring the axes of the osseous and cartilaginous meatuses, which form an angle in their natural position, into a straight line, so as to obtain an unobstructed view of the membrane.

The hard rubber, or slightly warmed metallic speculum, is then inserted so far into the cartilaginous meatus with a slight rotatory movement of the thumb and forefinger of the right hand until the hairs, which obstruct the view, are completely turned aside. The introduction of the speculum, especially in old individuals, occasionally causes a troublesome reflex cough
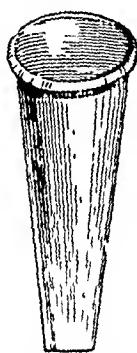
FIG. 84.—WILDE'S SPECULUM.   FIG. 85.—EHRHARD'S SPECULUM.   FIG. 86.—THE AUTHOR'S VULCANITE SPECULUM.
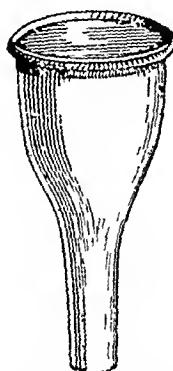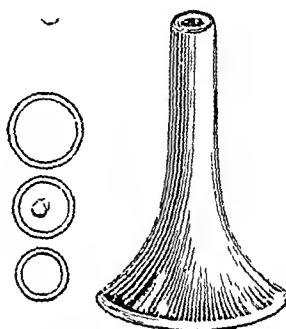
by irritation of the auricular branch of the vagus, and in rare cases fainting spells and epileptic convulsions. If the speculum has been inserted as far as the osseous meatus, which is recognized by a slight resistance, any attempt to push it further must be avoided in order to prevent painful pressure. The light is now thrown through the speculum into the auditory canal, and in order to view the different parts of the drum, it is necessary to vary the position of the speculum with the free left thumb.

In spite of these precautions, we sometimes obtain an incomplete view of the membrana tympani; this is due to various obstructions which lie either in the cartilaginous or in the osseous meatus. Among these the following may be mentioned: an abundant growth of hair extending into the osseous meatus; plugs of cerumen occluding the meatus, or adhering to the walls and narrowing its lumen; lastly, glistening epidermic scales, which are suspended in the canal as white membranes and bridges, and sometimes have the colour of mother-of-pearl.

Large quantities of cerumen and detritus are best removed by softening and syringing. Fatty deposits, small quantities of

mucus, pus, and blood, may be removed with small cotton
tampons.   The author recommends the use of his ear forceps
for the removal of small particles of cerumen, detached epidermic
scales and membranes.

The hindrances to examination which arise from congenital
stenosis of the meatus, or from abnormal bulging of the anterior
inferior wall of its osseous portion, are more important, because
their removal is impossible.   Such a constriction prevents the
entire membrane from being sufficiently illuminated; when the
anterior wall of the meatus is more or less bulged, the view of
the membrane is obstructed to such an extent that the portion in
front of the handle is either partially or completely hidden, and
sometimes the handle is so completely masked that only a
portion of the posterior superior quadrant of the membrane can
be seen.

The pathological changes which render examination of the
membrana tympani temporarily or permanently impossible
are inflammatory affections of the lining membrane of the
meatus, with swelling, infiltration and narrowing of the same,
as well as accumulations of epidermis, pus and mucus, granula-
tions, polypi and exostoses.

Normal Condition of the Membrana Tympani.—The following
points require our special attention in the examination of the
membrana tympani: colour, transparency, lustre, inclination,
curvature, position of the handle and short process of the malleus,
as well as Shrapnell's membrane.   The relation of these to each
other constitutes the characteristic picture of the normal as well
as of the pathological drum membrane.

Colour.—In reference to the colour of the normal tympanic
membrane, we must remember that it is a translucent, so-called
cloudy medium which reflects a portion of the light thrown
upon it, and allows a portion to penetrate, thereby illuminating the
tympanic cavity.   A portion of this light, slightly weakened,
is again reflected through the membrane from the inner tympanic
wall, and in this manner reaches our eye.   The colour of the
membrane is, therefore, composite, and depends on its intrinsic
colour, the kind of light employed, and the quantity and colour
of the rays reflected from the promontory.   The nature of the
light which is employed has a decided influence on the colour
of the membrane.

The various segments of the membrane being at different
distances from the inner tympanic wall, it follows that the indi-
vidual parts of the membrane present different colours, even if
the same light is employed throughout the examination.

The colour of the normal membrane is a neutral or pearl gray,
with a slight brownish-yellow tinge.   The gray is darkest in the
anterior portion, at the angle between the manubrium and the
cone of light, and is of a lighter shade in the posterior part.

The colour of this latter portion is in some cases modified at its superior part by v. Tröltsch's pouch and the chorda tympani. They are situated on the inner surface of the membrane, and shine through translucent membranes as a slightly concave, whitish-gray opacity, extending backwards from the handle of the malleus. When the membrane is transparent, the lower part of the long process of the incus (Figs. 87 and 88) is visible in the posterior superior quadrant behind the handle of the malleus; at times the posterior crus of the stapes and the tendon of the stapedius are also plainly discernible. The membrane appears slightly yellowish-gray behind and a little above the inferior extremity of the manubrium; this is brought about by the bone-yellow rays reflected by the promontory. This colour is often combined with a peculiar lustre, which arises from a moist, smooth spot of mucous membrane at the apex of the promontory. The recess or niche of the round window is represented by a dark spot in the posterior inferior quadrant of the membrane.

FIG. 87.—NORMAL MEMBRANA
TYMPANI OF THE RIGHT EAR.

FIG. 88.—NORMAL MEMBRANA
TYMPANI OF THE LEFT EAR.

(Double the natural size.)

Gomperz* described a rare condition of the membrana tympani in the form of a blue discoloration in its lower part; this reached to the umbo, and was caused by the bulbus venæ jugularis bulging into the inferior part of the tympanic cavity.

In examining the tympanic membrane, our attention is next drawn to the short process of the hammer (Figs. 87 and 88), which protrudes outwards and forwards at the anterior superior pole of the membrane as a white, sharp or rounded protuberance. It is continuous with the manubrium, which extends, as a yellowish-white stripe, backwards, downwards, and inwards, and ends at the umbo in a gray spatula-like expansion.

The umbilical opacity, or so-called 'yellow spot,' minutely described by Trautmann, is caused partly by the radiating and descending fibres of Prussak at the umbo, and partly, as the author has shown, by the deposit of small cartilaginous cells

* *Wien. med. Wochenschr.*, 1895.

round the lower extremity of the manubrium. A linear opacity, corresponding to the annulus tendinosus, is often seen at the anterior inferior periphery of the membrane.

Lustre.—The lustre of the membrana tympani is pronounced at the sharply defined triangular cone of light at its anterior inferior quadrant (Figs. 87 and 88). This light-reflex commences with its apex in front of the umbo, and enlarging as it extends forwards and downwards, forms an obtuse angle with the handle of the malleus. The greater the inclination of the tympanic membrane to the axis of the auditory canal, the smaller will be the angle formed by the handle of the malleus and the cone of light.

The shape of this light-reflex exhibits manifold variations, which are caused partly by the differences in the inclination of the membrane and partly by changes in its curvature. It is often interrupted in its continuity, and sometimes appears divided in its longitudinal or transverse direction; occasionally, however, it may be delicately striped. This reflex rarely reaches to the periphery of the membrane, and often its anterior portion is effaced, so that only its apex is visible as a small, irregular, lustrous spot in front of the umbo. Bezold, in examining the membrane of persons with normal hearing, found this bright spot blurred in 86 per cent. of cases. The knowledge of all these variations in the normal state is of importance, because if not observed they might easily give rise to an erroneous diagnosis.

In order to ascertain the origin of the light-reflex, the author undertook a series of experiments (*A. f. O.*, vol. i.) on artificial drum membranes and on normal specimens, which showed that it was principally caused by the inclination of the membrana tympani and the concavity produced by the handle of the malleus. The curvature produced by this inward traction induces such a change in the inclination of the membrane that its anterior part is placed opposite to our axis of vision, and the light cast upon this segment is again reflected to our eye. The triangular shape of the cone of light is caused, according to Trautmann, by the funnel-shaped inward curvature of the membrane.

The form and size of the light-reflex suffer many changes through abnormal bulgings of the membrane in diseases of the middle ear, and are of diagnostic value if we have an opportunity of observing these changes during the course of the disease. On the whole, however, these changes are of value only in conjunction with other symptoms, as similar alterations are frequently observed in persons of normal hearing.

On the other hand, changes in its form which arise from variations of air-pressure in the tympanic cavity are of diagnostic importance, and can be used in many cases in determining the permeability of the Eustachian tube. If we therefore perceive an alteration in the cone of light after the condensation or rarefaction of air in the tympanic cavity, we can say with certainty that the tube is permeable. But the absence of a change in the light-reflex does not permit us to come to a contrary conclusion, as often during rapid and

great changes in the air-pressure not the slightest motion of the membrane is visible, while a change in its curvature must have taken place, as was made evident by the motion of the drop of fluid in the manometrical tube, which had been hermetically introduced into the meatus (p. 59).

We find other reflexes on the normal membrane besides this cone of light. Occasionally a faint lustre is seen on the posterior superior quadrant, and at times a small reflex on the short process of the malleus and in the depression of Shrapnell's membrane. Another linear reflex must finally be mentioned, which is called by Bezold *sulcus reflex,* and is located at the anterior inferior periphery in the groove formed by the membrane and the sulcus tympanicus.

Inclination.—The inclination of the membrane in the living appears to be much less than in anatomical specimens. This is of great importance in judging changes on the membrana tympani, in considering its form and extent, and in operative procedures. Our judgment as to the inclination of the membrane is often so influenced by the width of the osseous meatus that it appears more perpendicular in a wide than in a narrow meatus. As the author was first to point out, we see, in consequence of the marked inclination of the drum, the pathological changes perspectively shortened—that is, different than they really look when the membrane is seen as a flat surface in anatomical specimens.

Curvature.—The curvature of the membrane is also important in judging pathological conditions. It varies in different individuals just as does the inclination. Our judgment as to the degree of curvature in the living is likewise apt to be erroneous, inasmuch as it seems to be less concave than is really the case. According to the examinations of the author, the transparency of the membrane exercises an important influence upon our judgment as to its curvature. When the membrane is very transparent, it appears less curved; when it is very opaque, however, the funnel-shaped concavity on its external surface becomes more prominent.

If we review the foregoing, the following structures are met with on the normal drum: (1) *The short process of the malleus,* projecting as a white spot at the anterior superior pole of the membrane (Figs. 87, 88); (2) *the handle of the malleus,* a white or bone-yellow stripe, which arises from the former and extends backwards, downwards, and towards the centre of the membrane, to end in its broad, spade-like expansion; (3) *the cone of light,* triangular in shape, situated in front of, and below the extremity of the handle, with its apex at the umbo and its base directed forwards and downwards towards the periphery; (4) the anterior portion of the membrana tympani between the handle of the malleus and the cone of light, generally dark gray, and seldom seen in adults as far as the periphery, but in children in two-thirds

of the cases (Bezold); (5) the portion of the membrane behind the manubrium separated from the superior wall of the meatus by a light gray line. It appears larger and lighter than the rest of the membrane, and has its colour modified by the rays reflected from the promontory. Sometimes the colour of this segment undergoes a change owing to the long process of the incus, v. Tröltsch's pouch, a portion of the chorda tympani, and, in rare cases, by the dark niche of the round window shining through.

Pneumatic Speculum.—We must still add to the above the important method of examination with Siegle's speculum, which is indispensable in the diagnosis of middle-ear affections. This instrument (Fig. 89) differs from the ordinary speculum in that its wide end is closed by an obliquely-set glass plate which is inserted into the speculum as far as possible in order to avoid the annoying light-reflex. At the side of its broad portion a short nipple-like projection is found, to which a rubber tube, provided
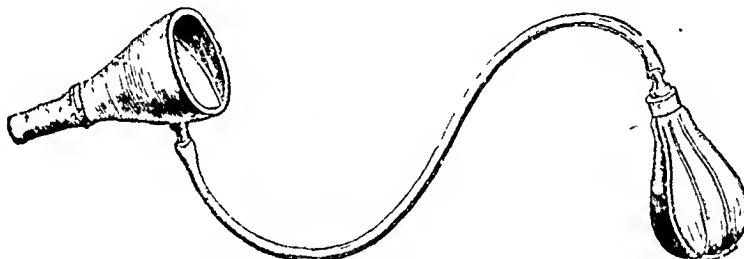
Fig. 89.—Siegle's Pneumatic Ear Speculum.
(Speculum ½ size, air-bag ¼ size.)

with a small air-bag, is attached. The hermetical introduction of this instrument into the external auditory canal, of which there are three sizes, is accomplished by an olive-shaped nozzle (Delstanche) or by covering the lower end of the speculum with a short piece of elastic tubing. In place of this speculum we may use the electric auriscope, which likewise serves as a pneumatic speculum, and allows one also to condense and rarefy the air in the external meatus; instead of the plain obliquely set glass plate, there is a magnifying lens, which has the advantage of giving one an enlarged image of the drum.

The examination is carried out in such a manner that the speculum, which is introduced into the meatus, is fixed with the left hand so that the reflex from the glass plate will not interfere with the view of the membrane. The membrana tympani is then illuminated with light reflected from the mirror attached to the forehead, and the air in the meatus is alternately condensed and rarefied by means of the air-bag. In suppurative affections the outer surface of the glass plate should be warmed before the examination, in order to prevent the inner surface from becoming dim.

When examining a normal membrane by this method, the greatest mobility is observed midway between the handle of the malleus and the periphery. The movement of the membrane is made most evident by the change in form of the cone of light, which becomes considerably smaller

during condensation. A distinct excursion of the handle of the malleus is simultaneously observed, and during condensation either its inferior extremity, or the handle as a whole, moves backwards and inwards. This mobility is subject to manifold changes in diseases of the middle ear, inasmuch as it becomes completely or partially lost through thickening and inflexibility of the membrane, through adhesions of the membrane with the promontory, through rigidity and ankylosis of the malleo-incudal articulation, or, finally, through adhesion of the head of the malleus to the superior tympanic wall.

The pneumatic speculum, as Siegle had already demonstrated, is used with advantage in cases in which it is required to ascertain whether the mobility of the membrane is diminished through thickening of its layers, or whether its mobility is increased through atrophy and the formation of cicatrices; it is furthermore of value to ascertain whether the drum membrane itself or parts of it are adherent to the inner tympanic wall. Examination shows that those portions of the membrane which are united with this wall remain either immovable during condensation and rarefaction of air, or exhibit only slight excursions, while those parts which are non-adherent show a considerable mobility. It can also be used with advantage in doubtful cases to establish the differential diagnosis between cicatrices and perforations of the drum membrane (Bloch). When the blood-vessels of the membrana tympani are markedly injected, we notice that their fulness disappears when the air is condensed with the pneumatic speculum, and that they return to their former state immediately after removal of the air-pressure.

B. Methods of Examination of the Middle Ear.

Those methods of examination which we employ in order to ascertain the condition of the Eustachian tube and tympanic cavity hold a prominent place in the practice of otology. By their aid we are able to obtain information as to the permeability of the Eustachian tube, the presence of pathologic conditions in the middle ear, and the state of the membrana tympani. These methods, however, are of still greater importance in the treatment of middle-ear affections, as they afford us a means of conducting therapeutic agents, such as compressed air, gases, vapours, or fluids into the tympanic cavity. These methods are:

1. **Valsalva's Method.**
2. **Catheterization of the Eustachian Tube.**
3. **Politzer's Method.** Author's method for effecting the permeability of the Eustachian tube.

Before commencing the description of these methods it seems necessary, in order to estimate their therapeutic value, to make a few remarks about the mechanical action of compressed air in diseases of the middle ear.

Mechanical Action of Currents of Air introduced into the Tympanic Cavity in Diseases of the Middle Ear.

The aim of the methods about to be described is to effect the permeability of the Eustachian tube for diagnostic purposes, and 'to conduct compressed air into the middle ear in order to remove or lessen obstacles in the sound-conducting apparatus which impair the function of hearing.

The effect of a current of air which is forced from the pharynx to the middle ear first acts upon the Eustachian tube, inasmuch as its walls, which lie in contact in the normal state, are forced apart, and its lumen widened. If the tube is narrowed by swelling and tumefaction of its mucous membrane, or by an accumulation of secretion, so that its pharyngeal orifice cannot be opened by an act of swallowing, its permeability and the uninterrupted communication between the tympanic cavity and the pharynx can be re-established by the forcible introduction of a current of air. By the action of such a current, the secretion deposited near the pharyngeal orifice is forced into the throat, while that in the superior portion of the tube is driven into the tympanic cavity.

The effect of this current of air upon the Eustachian tube, which has become impermeable through swelling of its mucous membrane, is by no means temporary. Experience shows that the constricted tube is often permanently dilated by the pressure of the air on its walls, inasmuch as, through the repeated action of the air-current upon the hyperæmic and swollen mucous membrane, the blood is gradually forced out of the dilated vessels, so that the swelling is lessened or entirely removed.

Air forced into the tympanum causes the drum membrane to bulge towards the lumen of the external auditory canal. The malleus follows this motion on account of its intimate relation with the membrane, while the incus and stapes do so only to a slight degree. In diseases of the middle ear the membrana tympani and the ossicular chain are often abnormally retracted, and the propagation of sound thereby hindered. This can be overcome by the forcible introduction of a current of air into the tympanic cavity, whereby the membrana tympani and ossicles are forced back into their normal position, and the abnormal tension of the sound-conducting apparatus is not only removed, but its power of vibration is partially or totally restored.

We have learned from experience that where a marked degree of deafness exists through closure of the Eustachian tube, a striking improvement takes place immediately after the propulsion of air into the middle ear. In a similar manner, through the forcible introduction of air into the middle ear, anomalies of tension in the sound-conducting apparatus which are caused by the inflexibility of the ossicular ligaments, by retraction of the tensor

tendon, and by newly-formed bands of connective tissue between the membrane, ossicles, and tympanic walls, are lessened or entirely removed, inasmuch as the tympanic membrane and ossicles are pushed outward and the tense ligaments and bands become stretched.

The air-current, entering the tympanic cavity, exercises pressure not only upon the inner surface of the membrana tympani, but also upon the fenestræ rotunda and ovalis. If the tissue closing the labyrinthine windows has been made inflexible through inflammatory thickening, it will become relaxed by repeated application of the air-douche, and the sound conduction to the labyrinth will be thereby greatly improved. Variations in the air-pressure in the tympanic cavity have an important influence on the relative pressure in the labyrinth (p. 60). Inflammatory affections of the middle ear are frequently associated with increased pressure in the labyrinth, induced partly by the pressure of exudate on its two fenestræ, and partly by increased tension in the sound-conducting apparatus. Therefore, a current of air forcing the membrana tympani, ossicles, and foot-plate of the stapes outwards will either lessen or entirely remove the abnormally increased labyrinthine pressure, as well as the subjective noises and disturbances of hearing accompanying it.

Inflations into the middle ear exercise, furthermore, an important influence upon the removal of secretion. This mechanical action of compressed air depends on the condition of the membrane—in other words, whether it is perforated or intact. The opinion that in non-perforative catarrhs the improvement in hearing following an air-douche is due to the removal of the secretion has been considerably modified by the results of the author's experiments on human ears.* These experiments showed that the larger portion of the secretion, especially if tenacious, remained in the cavum tympani even when a strong current of air was used, and that the improvement in hearing immediately following the air-douche was brought about chiefly by the removal of the abnormal tension in the tympanic cavity.

Thin fluid exudate in the middle ear is often partially or completely removed by an inflation of air if (as was shown by the author) the head of the patient is strongly inclined forwards and to the side opposite the affected ear. By this manœuvre, the position of the tube, which is normally horizontal, and opens directly under the roof of the tympanic cavity, is so altered that the tympanic orifice, which now lies lower than the floor of the middle ear, comes to lie on a higher level than the pharyngeal orifice, so that when the tube is opened by an inflation, the fluid gravitates from the tympanic cavity into the naso-pharynx.

There are a number of cases in which the exudate cannot

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* *Ueber bewegliche Exsudate in der Trommelhöhle.* *Wien. med. Presse,* 1869.

be removed by the repeated mechanical action of the air-douche; cure, nevertheless, takes place, and must be attributed to the absorption of the exudate, which is brought about by the re-establishment of the normal air-pressure in the tympanic cavity. In those secretory catarrhs accompanied by impermeability of the tube, the blood and lymph vessels of the mucous membrane are under a subnormal pressure owing to the rarefaction of the air in the tympanic cavity, thus causing a condition highly conducive to exudation.

The author is of the opinion that, by propelling air into the tympanic cavity in these cases, the circulation in the blood and lymph vessels again becomes normal on the re-establishment of the normal air-pressure, and the absorption of the secretion is thus effected. He came to this conclusion from the observation of cases in which an acute inflammation of the middle ear, accompanied by marked injection and opacity of the membrana tympani, had lasted for several weeks or months, and in which no increase in the hearing distance was observed previous to treatment. If, in such cases, an inflation was given, an immediate improvement in the hearing took place, and as this improvement steadily increased by the daily application of the air-douche, a striking change was generally observed in the membrana tympani. First, the injected radiating vessels disappeared, which was followed by the peripheral corona vascularis; then the membrane became more transparent, its lustre returned, and, with the improvement in hearing, the membrana tympani had, as a rule, regained its normal appearance.

From these observations it is evident that the exudate which has become stagnant through closure of the tube, and the abnormally decreased air-pressure in the tympanic cavity, keep up the hyperæmia in the middle ear; this is made manifest by the dilated vessels on the external surface of the membrana tympani. The rapid disappearance of a long-lasting hyperæmia, and hardness of hearing, after several applications of the air-douche, demonstrates its favourable effect in bringing about a normal condition of the circulation, and the absorption of the exudate in the middle ear.

The effect of an inflation of air when the membrana tympani is perforated is essentially different. The secretion deposited in the tube and in the tympanic cavity will be expelled into the external auditory canal, and pus as well as mucus are thus removed from the middle ear. The current of air has the same effect in removing exudate from the middle ear where the membrana tympani has been artificially perforated.

The view that in perforative inflammations of the middle ear purulent secretion is driven into the mastoid cells by the air-douche has been disproved by Michael (A. f. O., vol. xi.), who demonstrated experimentally that the secretion is always expelled into the external meatus.

1. Valsalva's Method.

Valsalva's method consists in condensing the air in the naso-pharynx by a strong act of expiration with the mouth and nostrils closed, whereby the walls of the Eustachian tube are separated and the air is forced into the tympanic cavity.

The manometric expiratory pressure in the naso-pharynx produced with closed nostrils varies according to the age of the individual, and according to the strength of the expiratory muscles.

In performing Valsalva's method its effect is influenced by the condition of the Eustachian tube and the state of the membrana tympani.   As the walls of the Eustachian tube lie more or less in contact in the normal state, the expiratory pressure necessary to force air into the middle ear must consequently be greater the closer its walls lie in contact.   The membrane also forms a marked barrier to the air entering the tympanic cavity, inasmuch as a considerable pressure must be brought to bear in order to overcome the resistance of the normally retracted membrane and to force it towards the external auditory canal.

The entrance of air into the tympanum during this method can be proved by inspection of the membrane, and by auscultation.   By inspection we notice an outward movement of that part of the membrane situated between the handle of the malleus and the periphery.   A diminution in the size of the cone of light will also be noticed, inasmuch as it becomes shorter and narrower, and in rare cases may even disappear. Not infrequently a slight excursion, outwards and forwards, of the inferior extremity of the manubrium takes place, but often all evidence of motion of the membrane is lacking during the application of this method.

The air forced into the tympanic cavity produces a noise which can be heard by placing the ear against the concha of the patient, or, better still, with the auscultation tube as proposed by Toynbee (Otoscope, *v.* Catheterization of the Eustachian Tube).

According to the experiments which were carried out by the author on fresh specimens of the ear, it was shown that this short puffing sound is caused by the outward movement of that portion of the membrane between the handle of the malleus and the periphery.   It is often preceded by a weak murmur due to the friction of the air in the Eustachian tube, and is generally designated as ' the sound of concussion of the membrana tympani.'   The short puffing sound is therefore produced by the movement of the membrane itself, and ought to be called ' the bulging noise of the membrana tympani.'

Since the Valsalvan method has often proved insufficient in forcing air into the middle ear of healthy individuals on account

of its low pressure, it has proved of still less value in diseased conditions. Hartmann found that even if there was a slight swelling of the mucous membrane of the tube, as often occurs in naso-pharyngeal catarrhs, the manometric pressure had to rise to 100–120 mm. Hg before the Valsalvan method was successful. A considerable increase in pressure is required in those affections of the middle ear accompanied by marked swelling of the tubal mucous membrane, inasmuch as this acts as an obstruction to the current of air, and often cannot be overcome even by the greatest expiratory pressure.

This is especially the case in those affections of the middle ear which run their course without perforation of the membrana tympani. Besides the obstructions in the tube, such as swelling, plugs of mucus and crusts and connective-tissue strictures, the difficulty of forcing air into the middle ear is also increased by the accumulation of secretion in the tympanum, by the tension of the membrana tympani, and by the firm adhesion of the walls of the tube caused by rarefaction of the air in the cavum tympani. It must, however, be mentioned that the Valsalvan method is successful in some rare cases in which air cannot be forced into the tympanic cavity, or only with difficulty by catheterization or by the author's method.

In that group of affections of the middle ear, however, in which the membrana tympani is perforated, the Valsalvan method may frequently be used for the purpose of diagnosis. In such cases, the resistance of the membrane is absent, and a counter-opening is thus formed in the tympanic cavity, which considerably facilitates the entrance of air through the tube. Although in many cases of perforation of the membrane the exit of the air through the meatus during the Valsalvan method is accompanied by a perceptible sound, it must not be inferred from the absence of this noise that the membrane is intact, inasmuch as extensive swelling of the tubal mucous membrane, granulations and inspissated secretion in the cavum tympani and in the external auditory canal, can also prevent the entrance of air into the middle ear.

If we review the foregoing, it is evident that the Valsalvan method can be used only in a small number of cases as a means of diagnosis. If it gives a positive result, we may generally infer that the mechanical obstruction in the Eustachian tube is slight; if, however, the result is negative, we may assume, in cases in which the membrane is intact, and especially in perforative inflammations of the middle ear, that there is an obstruction in the Eustachian tube or in the middle ear. From the author's experience, these results are quite important as regards prognosis; for in inflammations of the middle ear accompanied by swelling and secretion the prognosis, in regard to the rapid removal of the pathological changes, will, on the whole, be more

favourable in cases in which the permeability of the tube can be effected by the Valsalvan method than in those in which the application of the catheter or the author's method is necessary. We therefore always begin the examination of the middle ear with the Valsalvan method, and follow it by the application of the author's method and catheterization.

The therapeutic value of the Valsalvan method will be discussed in the chapter in which the effects of the methods enumerated at the beginning of this chapter are compared.

We must still mention Toynbee's experiment. It consists in performing an act of swallowing with closed nostrils, whereby a feeling of fulness in the ears is experienced, which was erroneously attributed by Toynbee to condensation of the air in the middle ear. This experiment is, however, of little value, because the auscultatory cracking sound heard in the normal ear is often absent, but is frequently audible in pathological cases, in spite of the impermeability of the tube. This experiment is equally unreliable for purposes of inspection, because in normal ears every evidence of movement of the membrane may be wanting, and, conversely, movements of the membrane may be perceived with impermeability of the tube and with secretion in the tympanic cavity.

2. Catheterization of the Eustachian Tube.

This method consists in the introduction of an Eustachian catheter into the tube, either through the nose or more rarely through the mouth, and is one of the most important procedures used in diseases of the ear. By the use of the catheter, we gain more reliable information as to the state of the middle ear than with the other methods of examination. It is also indispensable as a means of conducting vapours or fluids into the tympanic cavity for therapeutic purposes. Owing to the importance of this subject, we will first describe the anatomical structures of the naso-pharynx met with in performing catheterization.*

The Topography of the Pharyngeal Orifice of the Eustachian Tube.—The pharyngeal orifice of the Eustachian tube (Fig. 90, *h*) is situated on the lateral wall of the naso-pharynx, nearly on a level with the horizontal prolongation of the inferior turbinated bone. It is an oval depression, bounded in front by an ill-defined swelling, above and behind, however, by a strong, firm lip projecting towards the pharynx. The anterior lip is separated from the lateral wall of the nose by the sulcus nasalis posterior. An extensive

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* The discovery of catheterization was first ascribed to a postmaster named Guyot, who, in a report sent to the Paris Academy, 1724, gave an account of his own cure by means of a tube introduced into the Eustachian tube through the mouth. Catheterization through the nose was first performed by Archibald Cleland, but, according to the French, by Petit. The diagnostic and therapeutic importance of catheterization was first demonstrated by Saissy, Itard, and Deleau; later by Kuh, Kramer, Cerutti, and v. Tröltsch, and the indications for its use were at the same time established (*cf.* A. Politzer, *Ges. d. Ohrenh.*, vol. i., p. 321).

fold, the plica salpingo-pharyngea, extends from the posterior lip to the superior portion of the arcus palato-pharyngeus.

Rosenmüller's fossa (g) lies between the posterior lip of the tube and the posterior pharyngeal wall; it is rich in glandular tissue, and is subject to great individual variations in size. Chronic naso-pharyngeal catarrhs often give rise to cystic hypertrophy of the adenoid tissue and the formation of large gaps and bridge-like bands which may hold the beak of the catheter upon its removal. The distance of the orifice of the tube from the posterior pharyngeal wall will, therefore, not only vary in different individuals (average 1·8 cm., L. Mayer), but will also depend on the degree of swelling, hypertrophy, or growth of the mucous membrane of the naso-pharynx. For this reason, the distance of the pharyngeal orifice of the tube from the posterior pharyngeal wall cannot be used as a safe guide for the introduction of the catheter into the tube.
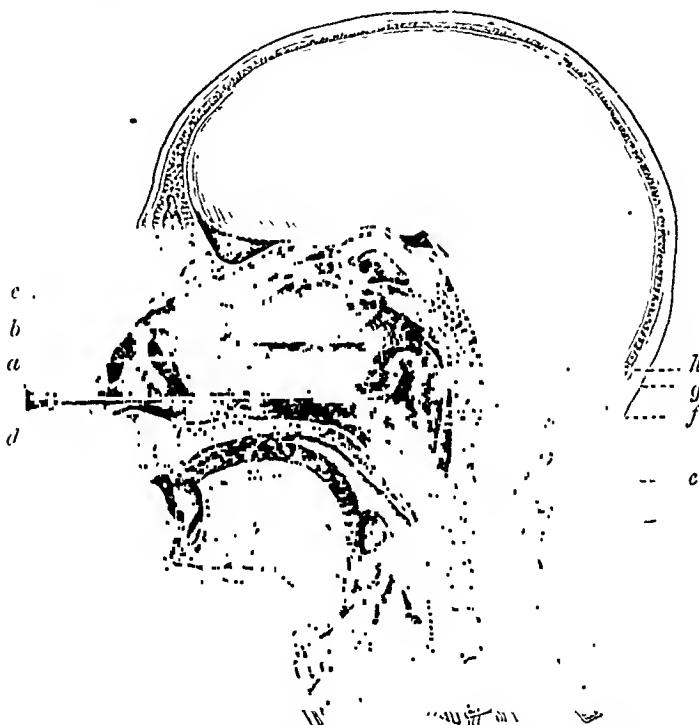
FIG. 90.—VERTICAL SECTION OF THE NASO-PHARYNX WITH THE CATHETER INTRODUCED INTO THE EUSTACHIAN TUBE.

a, Inferior turbinated bone; b, Middle turbinated bone; c, Superior turbinated bone; d, Hard palate; e, Velum palati; f, Posterior pharyngeal wall; g, Rosenmüller's fossa; h, Posterior lip of the orifice of the Eustachian tube.

The velum palati (e), which in the living arches upwards above the level of the hard palate, is situated below the orifice of the tube. The muscles extending from the tube and palatine arches give it a considerable degree of mobility, tension, and resistance. Every movement of the velum palati is associated with a simultaneous movement of the cartilagino-membranous part of the Eustachian tube; if the catheter comes in contact with the velum, or is introduced into the tube, its posterior extremity undergoes a perceptible change of position with every motion of the soft palate.

The three turbinated bones and the nasal septum deserve our attention on account of their relation to the Eustachian tube. The superior turbinated bone (c) is short and narrow, while the middle (b), and especially the inferior

(a), project further into the nasal cavity. Below these bones, and betweeen them and the lateral wall of the nasal cavity, the three nasal meatuses are situated, the lowest of which is of special importance in catheterization.

The distance of the ostium pharyngeum tubæ from the entrance into the nose is just as variable as the distance of the former from the posterior pharyngeal wall. As a general rule, this distance is less in females than in males; it is also subject to great variations in different skulls, inasmuch as it is usually greater in the prognathous than in the orthoprognathous type. Therefore, the distance from the nasal entrance to the pharyngeal orifice of the tube cannot, as has been proposed by Sabatier, be used as a guide in catheterization.

In performing catheterization, we must especially observe the frequent congenital and acquired deformities of the nasal septum and of the turbinated bones, as well as the obstructions caused by disease, which will be described later. If a considerable number of skulls are examined, it will be found that the nasal septum is seldom perpendicular; it is generally more or less deviated* to one side (more frequently towards the left), through which one half of the nose is greatly narrowed, while the other is correspondingly widened. In like manner, the permeability of the nose is often impaired by the excessive development of the middle, but more often of the inferior turbinated bone. This impermeability is more pronounced if an enlargement of the turbinated bones is associated with a deviation of the septum towards the same side, and there is at the same time a large nasal spine on its lower part.

Choice of Catheter.—The author invariably uses the smooth, hard rubber catheter, rounded at the end, and introduced into practice by him (Fig. 90A). Its length is 13–16 cm.,† the length of the beak 2–2½ cm., and its curvature 145°. A metal ring attached to the widened extremity corresponds with the concavity of the curvature of the beak, and indicates the direction of the point of the catheter when the instrument is in the naso-pharynx. As a rule, patients prefer a vulcanite to a metallic catheter. The unpleasant sensation caused by the contact of the latter with the mucous membrane is not experienced when using the vulcanite instrument. Moreover, when we meet with obstructions in the nose, the metallic catheters cause pain by pressure upon the rigid walls of the nasal passage; while those made of vulcanite, by reason of their elasticity, follow the curvature of the nasal cavity more easily. This moderate degree of elasticity, however, by no means impairs the firmness of the instrument, which is necessary to enable the practitioner to feel the sliding of its beak over the posterior lip of the tubal orifice, as well as the resistance offered by the posterior margin of the nasal septum.

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* Theile found the septum deviated 88 times in 117 skulls (_Zeitschrift f. rat. Med._, vol. vi.).

† The shorter catheters, as proposed by Lucae, have the advantage that they offer less resistance to the air passing through them; but when made of vulcanite they do not possess the same flexibility as the longer ones. The elastic catheters of Bonnafont and Rau have not been favourably received in practice owing to their great flexibility.
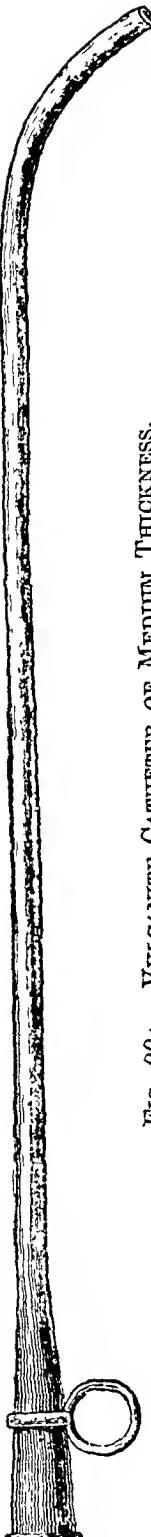
The objection that vulcanite catheters are easily broken is overruled by the fact that forced catheterization is never permissible.

It would be very desirable if catheters of a standard size could be introduced into general practice. The author uses catheters of four sizes, of which the diameter of the thickest, No. 4, is 3½ mm., No. 3, 3 mm., No. 2, 2½ mm. (most commonly used), and the thinnest, No. 1, 1½ mm.; the thickness of their walls is ½ mm. The catheters with an oval opening at the smaller end, which the author has lately introduced into practice, have the advantage that they fit more closely in the slit-like aperture of the tube; air and fluids can, therefore, be more forcibly injected into the middle ear than with the catheters with a round opening heretofore used. The long diameter of the oval opening is perpendicular to the curvature of the catheter.

The average curvature of the catheter as given above (145°) is not applicable for all cases. Where there are obstructions in the nasal and post-nasal cavities, which increase the difficulty of introducing and turning a normally curved catheter, it is necessary to change the angle of curvature either by gently warming it over a flame or by dipping it into warm water. The therapeutic effect of such slightly curved catheters is much less, as the point cannot be introduced far enough into the Eustachian tube.

On the other hand, it is occasionally necessary to use catheters with a long and strongly-curved beak. The application of such catheters is limited to those cases in which the permeability of the Eustachian tube cannot be attained with the ordinary catheter on account of marked resistance, or in those cases in which it is desired to inject large quantities of fluid into the middle ear. The deeper the point of the catheter is inserted into the tube, the more easily will air and fluid pass through its narrowest part into the cavum tympani.

The possibility of transmitting syphilis or other infection by means of the catheter necessitates the greatest care. In the author's practice a catheter is put aside for each patient, which is used throughout the course of treatment. Every busy practitioner ought to observe this precaution, not only to ensure the absolute safety of the patient, but also to lay aside all possible fear of infection. The instrument should be thoroughly sterilized immediately after use.

Technic of Catheterization.—Of the numerous methods of catheterization, two deserve a detailed description. These methods have fixed anatomical landmarks for the introduction of the catheter into the tube, and, from the author's experience, are not only the safest for the practitioner, but can also be substituted one for the other. These anatomical guides are the posterior lip of the tube with its rigid posterior fold (plica salpingo-pharyngea), and the posterior margin of the nasal septum.

Catheterization must be performed with the greatest care and consideration, in order to spare the patient every painful sensa-

FIG. 90A.—VULCANITE CATHETER OF MEDIUM THICKNESS.

tion.   It is, in the opinion of the author, of the greatest import-
ance that this procedure should be carried out in the sitting
position.   The patient sits facing the physician, on a chair with
a high back, so that the head cannot recede too far while perform-
ing the operation.   To introduce the catheter with as little
unpleasantness as possible, the point of the nose is turned up
with the thumb of the left hand, and the head steadied by placing
the remaining four fingers against the forehead.   The larger
extremity of the catheter is then seized, like a pen, with the
thumb and forefinger of the right hand, and is slightly depressed
while the beak is introduced into the nasal cavity.   The point of
the smaller end is applied to the nasal floor, and the larger
extremity is raised until the instrument is nearly in a horizontal
position; it is then pushed backwards while the beak is kept
constantly in contact with the floor of the nose.   When the nasal
cavity is normal, the catheter passes between the turbinated
bones and the nasal septum, without any noticeable change in
its original position, and then glides over the superior surface of
the soft palate to the posterior pharyngeal wall.   During this
entire manipulation the catheter must be held as loosely as
possible, so that its beak may easily evade any obstruction and
the patient be spared any unnecessary pain.

First Method.—The posterior lip of the tube is used as the
anatomical landmark in this method.   When the catheter has
reached the posterior pharyngeal wall, its beak is turned out-
wards, and gently forced into Rosenmüller's fossa.   The catheter
is then withdrawn with moderate rapidity, while its larger, free
extremity is somewhat raised and pressed against the nasal septum.
Thereupon the beak is felt to glide over the hard posterior lip
of the tube, which projects from the lateral pharyngeal wall.

After the point of the catheter has passed the posterior lip, it
has arrived at the pharyngeal orifice of the Eustachian tube.
To insert the beak into the tube, we turn the instrument outwards,
so that the metal ring at its larger extremity points towards the
outer canthus of the eye, or towards the pupil of the same side.
This direction of the beak corresponds, as a rule, with the axis
of the Eustachian tube.   By pushing the catheter gently back-
wards, it is possible to force the beak deeper into the canal.
Sometimes the catheter is also in the correct position when the
metal ring is horizontal.   This is known as the Bonnafont or
Kramer method.

Second Method.—The posterior edge of the nasal septum is
taken as the anatomical guide in this method, which was pro-
posed by Löwenberg.*

After the catheter has been introduced as far as the posterior
pharyngeal wall, in the same manner as in the previous method,
its point is not turned outwards, but *inwards*, towards the orifice

* *Arch. f. Ohrenh.*, vol. ii., p. 127.

of the other Eustachian tube; it is now brought into a horizontal position, which is recognized by the corresponding position of the metal ring.   The larger end of the catheter is then moved slightly outwards, and gradually withdrawn until its beak has reached the posterior margin of the nasal septum.   With moderate traction, a slight resistance is felt at this place, which prevents the further withdrawal of the catheter, and is due to the curvature of the beak encountering the posterior margin of the septum. Drawing the catheter too strongly against this slight resistance often interferes with the success of this method.   The catheter is now moved towards the nasal septum, and is held with the thumb and forefinger of the left hand close to the point of the nose; the beak is then directed downwards and rotated 180° on its long axis.   In this manner, the point of the beak is inserted into the pharyngeal orifice of the tube, provided that it is not displaced backwards or forwards during the rotation, and that no deformities exist in the posterior portion of the naso-pharynx and in the neighbourhood of the tubal orifice.   Some-times the tightly stretched velum palati offers great resistance to the downward rotation of the catheter, whereby, through in-sufficient fixation of the instrument, its point is forced backwards and its introduction into the tubal orifice is prevented.   If the instrument has entered the orifice, it is now in its proper position and fixed as in the previous method.

Fixation of the Catheter.—After the catheter has been intro-duced into the tube—a fact which can be ascertained by the auscultation sound of an inflation of air—it is seized immediately in front of the nose with the thumb and forefinger of the left hand, and firmly fixed in this position by gently resting the remaining three fingers on the bridge of the nose (Fig. 91).

In reference to the advantages and disadvantages of both methods, stress must be laid on the fact that Bonnafont's method is impracticable in cases in which the posterior lip of the tube is flattened or absent, either through ulceration, cica-tricial formation on the lateral pharyngeal wall, senile atrophy, or through disappearance in consequence of chronic catarrh.   It is, furthermore, impracticable where the catheter cannot be brought near the posterior lip of the tube on account of abnormalities of the turbinated bones and of the septum.   The execution of this method is also made difficult if the posterior lip of the tube cannot be found, in consequence of marked swelling in the posterior pharynx, or through granulations, adenoids, and new growths.

In such cases catheterization can be carried out more quickly and safely by the Löwenberg method.   Although this method has been used by Frank, Löwenberg and Giampietro, only in rare cases, the author has found* it to be an excellent method for

* *Zur Technik des Catheterismus der Ohrtrompete.   Wien. med. Presse,* 1872.

general use, as the skill necessary for its execution is more readily acquired than that of the other methods. But, on the other hand, it must be mentioned that it is impossible in some cases, even when the naso-pharynx is normal, as well as when there are obstructions in its posterior part, especially when there are defects of the nasal septum, to introduce the catheter into the Eustachian tube by this method, while it is effected without the least difficulty by the procedure first described. The value of these two methods lies principally in the fact that in many cases one supplements the other.

Other Methods of Catheterization.—In the extensively used method of Kramer, the catheter is pushed (according to the description of v. Tröltsch's, *loc. cit.*, p. 202)* to the posterior pharyngeal wall, and is withdrawn 2–3½ cm. (½–1½ inches); the beak, directed downwards, is then rotated
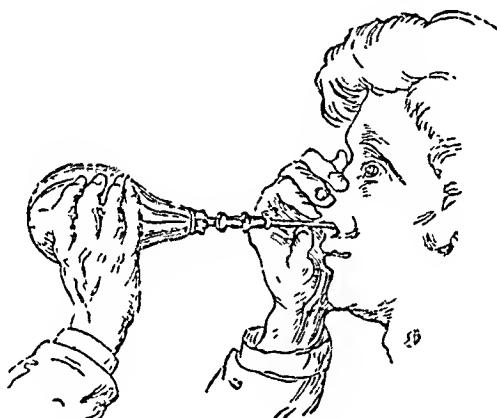
Fig. 91.—Fixation of the Catheter with the Left Hand after having been Introduced into the Eustachian Tube.

¾ of a circle outwards and upwards, whereby it ought to enter the orifice of the tube. The inefficiency of this method is best shown by the remarks of v. Tröltsch, who points out that the instrument is either withdrawn too much or too little; in the latter case it will enter Rosenmüller's fossa instead of the Eustachian tube.

In cases of great irritability of the soft palate and of the mucous membrane of the pharynx, catheterization after the above methods often produces spasmodic coughing and vomiting, which interfere with the execution of the operation. The following method can be recommended as most useful in such cases: The catheter is introduced with its point on the floor of the nose, and while being pushed backwards it is gradually turned outwards before it leaves the hard palate; by this manipulation the metal ring assumes an almost horizontal position. If the instrument is pushed backwards in this position, its point will enter the orifice of the tube without touching the soft palate, and will be prevented from reaching Rosenmüller's fossa by the posterior lip of the tube. The author very often applies this

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* This method differs from the description in Kramer's *Die Erkenntniss und Heilung der Ohrenkrankheiten* (1849, p. 484) in so far as mention is made of the sliding over the lip of the tube.

modification in a normal state of the naso-pharynx. In the method of Boyer and Gairal the beak of the catheter is turned 90° outwards after it has passed the inferior meatus; it is then pushed slightly outwards and upwards until its point enters the ostium pharyngeum tubæ. This method can be recommended only to skilled practitioners. The method recommended by Itard takes the distance between the anterior border of the alveolar process of the superior maxilla and the posterior border of the hard palate as a landmark, inasmuch as this is supposed to correspond to the distance between the orifice of the nostrils and that of the Eustachian tube; this method is decidedly inferior to the other methods, as its accomplishment is often uncertain.

A method, already described in the older works on ear diseases (Lincke, vol. iii., p. 359; and Rau, p. 117), consists in advancing the catheter to the posterior pharyngeal wall with its point directed downwards; it is then withdrawn until its beak meets with resistance at the soft palate, whereupon it is rotated outwards $\frac{2}{3}-\frac{3}{8}$ of a circle, and should enter the orifice of the tube. Catheterization by this modification, as with any other method, can be performed only after long practice. It does not afford the same certainty to the inexperienced as the first described methods, firstly, because the position of the soft palate varies considerably, and, secondly, because its variable tension and resistance yield more or less readily to the pressure of the beak of the catheter.

Mistakes in Catheterization.—The following may be mentioned as some of the mistakes which happen even under normal anatomical conditions, and which prevent the success of the operation:

1. The point of the catheter is not applied to the floor of the nose, but is pushed into the middle meatus, and detained there so tightly that its beak cannot be turned towards the pharyngeal orifice of the tube.

2. The catheter is correctly introduced to the posterior pharyngeal wall, but, on withdrawing, its larger end is not raised sufficiently, whereby its point reaches above the pharyngeal tubal orifice instead of gliding over the posterior lip.

3. The point of the catheter is correctly introduced into Rosenmüller's fossa, but, upon withdrawing, the posterior lip of the tube or a bridge of mucous membrane offers such a resistance that it may lead to the belief that the instrument is detained in the tube.

4. The beak of the catheter is drawn over the posterior lip of the tube, but instead of performing rotation immediately after its point has slid over the lip, which is necessary for its entrance into the tube, it is withdrawn still further. In this case, the point of the catheter is detained by the posterior extremity of the inferior turbinated bone, which may also give rise to the erroneous assumption that the instrument is in the tube.

5. The instrument is not turned sufficiently towards the Eustachian tube after it has passed the posterior lip; its point thus finds itself in the tubal orifice, but the direction of its beak does not correspond with that of the Eustachian tube. In like manner, if the beak of the catheter has not been inserted far enough into the canal, it may slip out through excessive rotation outwards and upwards. The point of the instrument will then have been directed towards the superior pharyngeal wall, which is made evident by the vertical position of the metal ring.

Modifications of Catheterization in Cases of Congenital or Pathological Obstacles in the Naso-pharynx.

—Besides the congenital anomalies already described, one not infrequently observes pathological obstructions in the naso-pharynx, which either make catheterization difficult or impossible. The following must be mentioned: deformities due to traumatic affections

of the nasal septum and of the turbinated bones; strictures of the nasal cavity from ulceration and caries; hyperostosis of the superior maxilla (Moos); polypi; cancer; sarcoma; adenoid vegetations in the naso-pharynx; concretions; and, lastly, temporary and not infrequent excessive swelling of the nasal mucous membrane.

The possibility of catheterization in the presence of such anomalies depends principally on the degree of stricture in the nasal cavity. If, during the introduction of a thick catheter, an obstacle is encountered which cannot be overcome by turning the instrument slightly to one side, a smaller catheter should be chosen. If the latter cannot be advanced, the operation must be attempted with a catheter the beak of which is less curved. The instrument having arrived at the place of obstruction, it is not advisable to force it further, as not only unnecessary pain is caused, but the nasal walls may also be injured. In order to overcome the obstruction, it is advisable to rotate the beak outwards, more rarely inwards, and at the same time to advance the instrument gently. The catheter will often execute a complete rotation during this manipulation, and cases frequently occur where two rotations of the instrument are necessary to effect a passage through the various obstructions in the nose in order to reach the posterior pharyngeal wall. If the obstruction is in the anterior portion of the nose, it can easily be discovered by examining the cavity with reflected light. It will often be perceived that the septum (spina nasalis), deviated strongly to one side, is in contact with the turbinated bones. In like manner, tumours and polypi in the anterior and middle portions of the nasal cavity can often be recognized. In cases, however, in which the stricture lies in the deeper portions of the nose, which cannot be immediately seen, one can come to a conclusion as to the cause and extent of the obstruction only after a thorough examination.

When one side of the nose is absolutely impermeable, it is recommended to perform catheterization from the other side, and if both nasal passages are occluded (occlusion of the choanæ, Schwendt), one may try to introduce the catheter through the mouth. Since the introduction of the author's method into practice, and where it is desired only to introduce air into the middle ear, these modifications have become unnecessary. The above modifications should be used only in cases in which the permeability of the tube cannot be effected by the Valsalvan experiment or by the author's method, or in which the injection of fluids into the middle ear or the introduction of bougies into the tube is indicated.

Catheterization of the Eustachian Tube from the Opposite Nasal Passage.—This method was first proposed by Deleau,[*]

* *Revue Médicale,* 1827.

and described by Cerutti,* as a generally applicable method in order to save the patient the unpleasantness of introducing the catheter through both nasal passages; it may be performed with an ordinary instrument in case of a narrow pharynx, or even in one of normal dimensions; in a spacious naso-pharynx it can only be accomplished with a catheter, the beak of which is 20–25 mm. in length.† The method of procedure is as follows: The catheter is introduced as far as the posterior pharyngeal wall, and its point rotated towards the opposite Rosenmüller's fossa until the metal ring assumes a horizontal position. Thereupon the point of the catheter is forced into Rosenmüller's fossa by moving its free end away from the nasal septum towards the ala of the nose; it is then conducted into the orifice of the tube by traction over its posterior lip, and is pushed into the canal by a gentle movement backwards. The fixation of the instrument in this position is also best accomplished with the thumb and forefinger of the left hand, the other fingers being laid on the bridge of the nose. It is often possible to bring the point of the catheter into the opposite ostium tubæ if one, after catheterizing, for example, the left side, rotates it to a horizontal position towards the right side without moving the instrument forwards or backwards.

Catheterization from the Mouth.—The indications for this method recommended by Störk, Pomeroy and Kessel are very limited. This operation is only performed when both nasal passages are impermeable, or when with impermeability of one side catheterization from the other side is found to be impossible. The author also uses this modification in cases of cleft palate, whether the orifice of the tube is visible through the gap or not. As the destructive processes in the palate are mostly combined with ulceration and deformities in the nasal cavity, the tube will generally be reached more easily from the mouth through the gap in the palate than through the nose.

The catheters used in this modification are of a somewhat thicker calibre. The ordinary curvature of the beak will generally suffice in cases of cleft palate. When the palate is intact, the catheter is introduced into the Eustachian tube in the following manner: It is placed upon the tongue (which is at the same time depressed), and is pushed to the posterior pharyngeal wall; behind the soft palate the point of the catheter is turned upwards, towards the lateral pharyngeal wall, and advanced as far as Rosenmüller's fossa. The instrument is now withdrawn until its point arrives at the orifice of the tube, which fact is recognized by the sensation of the instrument gliding over the posterior lip. By a slight movement backwards, the beak of the catheter is forced into the Eustachian canal. In those cases in which we can see the fold of the posterior lip running downwards, the ostium pharyngeum tubæ can be reached by simply placing the point of the catheter immediately in front of the superior part of this fold.

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* *Nuova osservazione dell' Cateterismo della tuba Eust. destra dalla narice opposta. Gaz. med. italiana Stati Sardi*, 1858.

† The vulcanite catheters can be made very soft by warming them over a flame or dipping them into hot water for a few seconds; they must now be lengthened and curved as quickly as possible to the desired form, as they harden rapidly, and possess a considerable advantage over the stiff, inflexible metal instruments.

In irritable conditions of the pharynx, catheterization through the mouth is rendered difficult and often quite impossible by continued choking and retching. The application of a solution of cocaine to the surrounding parts greatly facilitates the operation.

In spite of the frequent congenital and acquired anomalies in the naso-pharynx and nose, cases are rarely met with in which catheterization through the nose is absolutely impossible. Other causes are much more frequently met with in which, even with a normal naso-pharynx, insurmountable difficulties occur in carrying out this operation. This is especially true of children, who, almost without exception, rebel against this procedure. Adults often obstinately oppose catheterization, and not only nervous women and old persons, but even strong men, who are not very sensitive, display an aversion to this operation. It goes without saying that catheterization is contra-indicated in continued fever, weakness, and irritability during convalescence. Catheterization must not be performed in cases of acute rhinitis, in nasal suppurations as sinusitis, when there are ulcerations in the nose and in the naso-pharynx, and in acute otitis and angina, especially during the crisis of the disease.

Unpleasant incidents during catheterization are vomiting and retching, which occur especially when the instrument comes in contact with the soft palate, and which subside as soon as the catheter is introduced into the Eustachian tube. These incidents and the unpleasant pain and irritation can be easily overcome by first thoroughly cocainizing the nasal mucous membrane and posterior nares with a weak solution of cocaine. Such violent reflexes are sometimes observed with each inflation or injection of fluid into the middle ear, even when the catheter is in its proper position. Occasionally, however, this operation must be interrupted owing to attacks of dizziness, prolonged sneezing, spasmodic coughing, attacks of fainting, and hæmorrhages from the nose.

Technic of introducing Air into the Middle Ear through the Catheter for Diagnostic and Therapeutic Purposes.

Deleau deserves the credit of having introduced air into the middle ear for diagnostic purposes, and especially of first having extensively employed it in the treatment of diseases of the ear, in that he put into practice the results of the investigations of Laennec, and by doing so made a decided advance in the therapy of these diseases.

In order to introduce air into the middle ear, we generally employ a 10-ounce pyriform rubber bag (capable of holding 350–420 gm. of fluid), a double air-bag,* or compressed air. The air-douche, by means of the rubber bag, is performed in the

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* Bags with valves become useless in a short time.

following manner: The catheter is introduced into the Eustachian tube and fixed with fingers of the left hand; the corresponding ear of the patient is connected with that of the physician by means of an auscultation tube,* and the bag is seized with the right hand in the manner represented in Fig. 92; its nozzle is then tightly inserted into the free, large extremity of the catheter, and the air is propelled into the middle ear by compression.

The following precautions must be observed: The first compressions must not be made too rapidly or too forcibly, for if the catheter should happen to be pressed against the walls of the pharynx or tube, the mucous membrane might be injured by a powerful current of air. Should such a forcible inflation be now given, the air would penetrate into the submucosa of the pharynx and bring about an emphysema which is generally confined to the pharynx, but sometimes extends to the entrance of the larynx, as well as to the subcutaneous connective tissue of the face, the lateral region of the neck, and even to the thorax. On palpating this subcutaneous emphysema, a distinct crepitation can be felt.

The submucous emphysema in the pharynx, which is mostly caused by careless use of the catheter or by the forcible use of the bougie, brings about pain, difficulty in swallowing, and by the extension of the swelling towards the larynx, may also interfere with respiration to a varying degree (Pollak). Through prolonged reflex hawking, the emphysema increases during the first few hours; it is therefore important to instruct the patient to suppress as much as possible the act of swallowing or of clearing the throat for some hours. If the emphysema increases to such an extent as to produce difficulty in respiration, a means of escape for the air can be made by incising the mucous membrane of the pharynx with a sharp bistoury. As a rule, the emphysema disappears in a few days without treatment.†

From the foregoing it is evident that in all cases in which a marked resistance is encountered on compression of the air-bag the instrument must be somewhat withdrawn. By this action the orifice of the catheter, which has become occluded by pressure against the posterior wall of the tube, is rendered free, and the air can enter the canal unchecked. In order to avoid such incidents, caused by improper fixation of the instrument, it is advisable, with each compression, to press the catheter slightly towards the balloon with the thumb and index-finger of the left hand; the object of moving the catheter towards the bag is to counteract the pressure exerted on the catheter during compression.

The most powerful action of the bag is obtained when, as in Fig. 92, it is held with the thumb and palm of the hand and compressed on its side with the four fingers. On the other hand, the pressure is considerably less if the fingers are applied around the neck and the bag compressed at its base with the thumb.

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* This consists of a rubber tube about 70 cm. long, having an olive-shaped perforated tip at each end.

† The extension of the emphysema to the tympanic cavity, membrana tympani, and to the mastoid process is exceedingly rare.

If we hear the air entering freely into the middle ear during compression of the bag, the subsequent inflations should be rapidly and powerfully repeated. The therapeutic value of the air-douche depends principally on this mode of application. After each compression, the bag should be gently removed from the catheter, to allow it to become refilled with air.
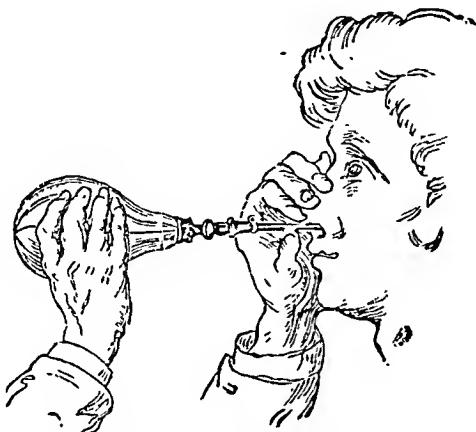
FIG. 92.—AIR-DOUCHE WITH THE INDIARUBBER AIR-BAG.

In place of the Politzer bag, compressed air is now universally used. The tank which contains the air is equipped with a pressure gauge so that we can regulate the amount of pressure as desired. The one end of a soft flexible tube is connected with the pipe leading to the air tank, while the other end has a small cut out which can be inserted into the outer end of the catheter, and the air thus forced through the Eustachian tube into the middle ear. This method of inflation has the advantage over the air-bag in that we know the exact amount of pressure used, and at the same time eliminate the necessity of removing and replacing the bag after each compression, as this is generally associated with a certain amount of discomfort to the patient. In the majority of cases 10–15 lbs. pressure are sufficient, although 20–25 lbs. may be required where there is marked obstruction in the Eustachian tube.

The Results of Auscultation in Normal and Pathological Conditions of the Middle Ear.

The importance of auscultation as a means of diagnosis of middle-ear affections has been very often over- and too often under-estimated. Although auscultation often gives a negative or indefinite result, in certain cases it leads to a positive diagnosis. It is always of value, however, if taken in conjunction with other symptoms.

The air propelled into the normal middle ear during catheterization produces a protracted, dry, blowing sound, which is heard by auscultation. This sound can be compared to that produced by placing the tongue against the hard palate, and quickly performing an act of expiration with the lips slightly apart. The friction of the air on the walls of the Eustachian

tube, the tympanic cavity, and on the inner surface of the membrana tympani, gives rise to this blowing sound (Deleau's *bruit de pluie*), which varies in strength and distinctness and is dependent on the individual variations in the calibre of the tube. Air forced into the middle ear enters more freely and with a more protracted sound if, during catheterization, the canal is opened by an act of swallowing. In order, therefore, to increase the therapeutic effect of the air-douche, it is advisable to make the patient repeatedly perform an act of swallowing.

The calibre of the catheter, the size of its smaller orifice, and its position with regard to the walls of the Eustachian tube, exercise a considerable influence on the pitch and intensity of the auscultation sound. When a catheter with a small lumen is employed, the sound will generally be higher and sharper than when using a catheter of a large calibre. A change in the auscultation sound may also occur during catheterization if the orifice of the catheter is narrowed through contact with the walls of the tube owing to a change in the position of the instrument.

The distinct sound of air entering the tympanic cavity during an act of swallowing does not justify us in coming to the conclusion that the catheter is properly inserted into the Eustachian tube, for air may enter the cavum tympani through the tube, which opens during the act of swallowing, even if the point of the catheter is situated in front of, or behind, the ostium pharyngeum tubæ.

The current of air in pathological cases occasionally reaches only to the isthmus tubæ, and produces a sound which bears a remote resemblance to that caused by air entering the cavum tympani; to the inexperienced, the former sound may easily be mistaken for the latter. It is differentiated by the fact that the former is much weaker and more subdued, and seems far more distant than the latter, which seems to be heard as if it arose immediately in front of the ear of the physician.

The auscultation sound caused by the air-douche is subject to many changes in diseases of the middle ear. To estimate the value of these pathological sounds, we must bear in mind that we generally have to deal with combination sounds, which are caused, partly by swelling and stricture of the Eustachian tube, by tumefaction of the mucous membrane of the middle ear, by pathological changes in the membrana tympani, and partly by exudate in the tube and in the tympanic cavity. It need hardly be mentioned that the strength of the air-current and the lumen of the catheter influence the quality of the sound.

When the membrana tympani is intact, the auscultation sounds differ considerably from those obtained when the membrane is perforated. The auscultation sounds produced under the former conditions are subject to many variations, and are influenced by the middle-ear affection; in other words, whether it runs its course with or without swelling and exudation. In cases of secretion in the middle ear, inconstant gurgling sounds of different quality are frequently heard during the application

of the air-douche. As a rule, their place of origin cannot be ascertained by auscultation (Offenorde).* These noises originate most frequently in the Eustachian tube, especially if it contains secretion (moist gurgling sounds), but are less often produced when there is a collection of secretion in the tympanic cavity. If a considerable amount of fluid secretion has collected, a very rapid, bubble-like rustling and crackling noise is frequently heard; this may even be audible without the auscultation tube, and often lasts for some time after the inflation. When there is a small amount of secretion in the tympanic·cavity, which may be diagnosed by inspection of the membrana tympani, all gurgling sounds may be absent. We seldom hear a distinct râle when thick, thread-like, tenacious secretion is present in the tube and tympanic cavity, but usually a rough, rattling, interrupted noise or a rough crackling which is frequently interrupted by a coarse friction sound; this latter noise is due to a simultaneous swelling of the tubal mucous membrane and to an altered tension in the membrana tympani. A distinct râle is sometimes heard only at the beginning of the inflation, which is then followed by a free auscultation sound. This is the case if the secretion lodged in the tube is removed by the first inflation of air, or if mucous secretion from the naso-pharynx remains adherent to the point of the catheter, and is forced into the Eustachian tube. The latter occurrence, which is frequently met with, is worthy of notice, because the gurgling noises thus produced may erroneously be interpreted as a hypersecretion of the tubal mucous membrane.

The gurgling sounds produced when the catheter is incorrectly placed in Rosenmüller's fossa, or near the orifice of the tube, are distinguished from those arising in the middle ear by the fact that they resemble the bursting of large bubbles, and seem distant from the ear when using the auscultation tube. In a like manner, grating sounds are often observed in the pharynx during the application of the air-douche, which are brought about partly by the vibrations of the membranous portion of the tube, and partly by the vibrations of the soft palate caused by the returning air.

The friction produced by the air on the inner surface of the membrana tympani gives rise to a distinct auscultation sound. This is proved by the fact that in cases of anomalous tension of the membrane, especially in scar formations, in drums relaxed through atrophy, in cicatricial adhesions between the membrana tympani and inner tympanic wall, and even with a normal condition of the Eustachian tube, a sharp, high, vibrating sound is often heard, which appears to be so near the ear of the examiner that it may easily be mistaken for the sound heard when the membrana tympani is perforated.

In catarrhs of the middle ear running their course without swelling or secretion, as in sclerotic processes so frequently associated with rigidity and ankylosis of the base of the stapes, the normal auscultation sound is almost always heard. In cases of diffuse thickening of the mucous membrane of the middle ear,

* *A. f. O.*, vol. lxvi.

and where the canal of the Eustachian tube is strictured through hypertrophy of its submucous connective tissue, one sometimes hears merely a very weak, dry, thin sound, at other times a high, sharp, whistling noise.

The auscultation sound, associated with perforation of the membrane, depends on the presence and quantity of secretion in the middle ear, on the degree of stricture of the Eustachian tube, and partly also on the size of the perforation. Accordingly we hear a hissing and gurgling noise which can be perceived even without the auscultation tube; but when the secretion is scanty, and the Eustachian tube strictured, the sound has a high, whistling character. If, on the other hand, the tube is dilated, as occurs after a suppurative inflammation of the middle ear has run its course, a blowing, puffing sound will be perceived, even if the perforation in the membrane is small. When we use the auscultation-tube, the air passing through the perforation reaches our ear directly, so that the sounds are heard as intensely and forcibly as if they had their origin in our own ear. The perforation sound may be entirely wanting when the opening in the membrane is occluded by inspissated purulent masses, by granulations in the tympanic cavity, or when the air is prevented from entering the cavum tympani through adhesions, connective-tissue masses, etc.

Laennec[*] has proved that air entering the middle ear produces a sound in he mastoid process which can be distinctly heard by auscultation. He also showed that gurgling noises in the middle ear could be perceived by auscultation at the base of the mastoid, and that their location could be determined. According to Michael,[†] a blowing sound is heard in pneumatic mastoid processes during catheterization. When the Eustachian tube is impermeable or when the membrane is perforated, no sound will be perceived on the mastoid process. If these two conditions can be excluded, and if the auscultation sound is absent, a diseased state of the mastoid cells may be inferred (exudation, cheesy masses, granulations, sclerosis). Percussion of the mastoid process will be discussed in the chapter on 'Diseases of the Mastoid Cells.'

The Methods of injecting Fluids and introducing Vapours into the Middle Ear through the Catheter.

The injection of fluids through the catheter is employed (1) to lessen the secretion, in swelling and hypersecretion in the middle ear, and to reduce the tumefaction of the diseased mucous membrane by the immediate action of the medicated fluid; (2) to bring about an irritation and a loosening of the rigid mucous membrane, thereby obtaining a greater mobility of the sound-conducting apparatus in those adhesive processes of the middle ear in which, as a result of thickening of the mucous membrane, there is a firm union of the ossicles with each other and with the tympanic walls; (3) to remove accumulations of inspissated secre-

* *Sur l'auscultation médiate*, 1835, p. 57.
† *A. f. O.*, vol. xi., p. 46.

tions in the middle ear through liquefaction; (4) in rare cases to render the tube permeable where the air-douche fails.

The quantity of fluid entering the tympanic cavity is the greater the further the point of the catheter is pushed towards the isthmus tubæ, and the more the orifice of the instrument corresponds with the direction of the tube. We are never able to judge how much of the fluid reaches the tympanic cavity, as a partial escape into the pharynx is unavoidable, owing to the funnel-shaped narrowing of the cartilagino-membranous tube, and to the angular bend of the tube at the isthmus.

The technic of injecting small quantities of fluid into the middle ear to effect a cure is as follows: After the catheter has been introduced into the Eustachian tube, air is injected two or three times into the tympanic cavity by means of the air-bag in order to remove secretion deposited in the tube, which would hinder the entrance of the fluid.

Thereupon a Pravaz syringe, fitted with a conical nozzle, is filled with a medicated fluid; this is slightly warmed, and 10–15 drops injected into the catheter under slight pressure, whereupon the fluid is driven into the middle ear by means of a forcible inflation with the air-bag. Care must be taken that the head of the patient remains in the erect position, because if inclined backwards the fluid in the catheter will escape into the pharynx before it has been forced into the middle ear. It is absolutely necessary to thoroughly sterilize the catheter, the syringe, and the injection fluid.

When the membrana tympani is intact, a sharp sound, accompanied by a fine crepitation, is heard as the fluid enters the middle ear, which may often last for some time after the injection. Inspection of the membrana tympani shows either an unaltered state, or injection of the vessels of the manubrium, rarely ecchymoses of a varying degree, or great congestion of those parts near the superior and posterior walls of the meatus; these changes may occur not only with the injection of irritating, but also with perfectly bland fluids. Small quantities of injected fluid are seldom seen by inspection of the membrane; on the other hand, large quantities may become visible when the membrane is transparent and the fluid coloured.

The subjective symptoms which arise after the injection of fluids into the middle ear are a sensation of fulness or warmth, sometimes of burning, more rarely of acute pain in the ear, and a temporary sensation of taste (Moos). Since the author has employed sterilized fluids for injection, he has seldom observed a severe reactive inflammation of the middle ear, and scarcely ever a marked suppurative process. The escape of a portion of the fluid into the pharynx often causes an unpleasant retching, hawking, and coughing, which are most quickly relieved by gargling with cold water. Acute pain in the ear after injection

is rapidly removed by massage of the parts around the auricle, or by pouring lukewarm water into the external meatus.

The technic of injecting larger quantities of fluid into the middle ear is as follows: A catheter with a long beak is inserted as far as possible into the Eustachian tube. For the purpose of injection, we use a rubber air-bag, capable of containing 100 grammes (No. 3), or a glass syringe, with hard rubber mountings, capable of holding 80–100 grammes (Fig. 93), the nozzle of which is hermetically introduced into the free end of the catheter. It is better to use a metal syringe fitted with a metal piston, inasmuch as it can be boiled. The greater the resistance in the middle ear, the more difficult is the injection of fluid; even with a permeable tube and a perforated membrane only a portion of the injected fluid escapes into the external meatus, while the greater portion, however, flows off into the pharynx and through the nose.
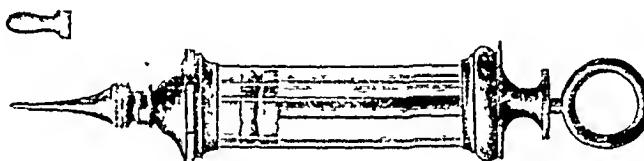
FIG. 93.—STERILIZABLE GLASS SYRINGE WITH HARD RUBBER MOUNTINGS. (AFTER GORHAM BACON.)

In cases in which the cavum tympani is either partially or wholly filled with inspissated secretion or by proliferated mucous membrane, and where the injected fluid cannot be forced into the tympanic cavity, but flows back into the pharynx, the elastic tympanic tube of Weber-Liel can be used with advantage. The author has found this instrument, which was originally intended for aspirating exudate from the cavum tympani and for the injection of medicated fluids, invaluable in the treatment of certain diseases of the middle ear, external meatus, and mastoid process, and almost indispensable in the practice of otology.

The tympanic catheter (Fig. 94) consists of a small flexible tube, funnel-shaped at its larger extremity; it is 17 cm. long and about 1–1¼ mm. thick, and has a small aperture at its smaller extremity.

In order to introduce this elastic catheter, we use a moderately large vulcanite catheter, 12 cm. long, through which the former is pushed into the tympanic cavity. Its point is in the tympanum when it projects 2½–3 cm. beyond the point of the vulcanite catheter; this is apparent by a mark previously made on its outer extremity. The catheter is held in position by the tympanic tube. The injection of fluid by means of the tympanic catheter is accomplished either with a graduated Pravaz's syringe, with a small rubber air-bag (No. 3), or with compressed air. The pressure must be only gradually increased, because if the outflow into the external meatus is prevented, violent pain and dizziness may arise from the sudden increase of the pressure of the injected fluid upon the tympanic walls.

Fluid injected, either by means of the catheter or by aid of the tympanic tube, enters the middle ear with a dull, rushing sound similar to that perceived when one places the ear against a rubber tube through which fluid is flowing. Even when fluid is injected through the tympanic catheter, a portion will escape into the naso-pharynx.

The injection of large quantities of fluid into the middle ear is applicable only in those affections in which a perforation of the membrana tympani exists, and where, therefore, the injected fluid may again escape into the external auditory canal. These injections are especially serviceable in those middle-ear inflammations in which dangerous symptoms arise owing to the stagnation of inspissated secretion, and where, therefore, it is necessary to liquefy and to remove it or to expel cholesteatomata. In fact, they can be employed in all middle-ear suppurations in which there is an acute intercurrent inflammation accompanied by severe pain, with or without a bone affection.

On the other hand, we must disapprove of the injection of large quantities of fluid in those middle-ear affections in which the membrane is not perforated. Deleau* and Bonnafont† have already pointed out the injurious consequences which follow such injections when the membrane is intact; their experience has shown that not infrequently a most violent reaction is produced, giving rise to a suppurative inflammation of the middle ear which may lead to fatal complications.

The technic of introducing bougies into the Eustachian tube will be described when we come to the treatment of strictures of the tube.

The Introduction of Medicated Substances in the Form of Vapour in the treatment of diseases of the middle ear was formerly more employed than now. Vapours impregnated with various drugs are still employed, and do, in some acute inflammatory conditions of the nasopharynx and Eustachian tube, prove beneficial in that they bring about a recession of the congestion and swelling of the mucous membrane, and consequently a decided improvement in the hearing.

In every vapour apparatus, the impregnated air enters the middle ear through the catheter with far less energy than if a simple inflation were given. Under such a weak pressure, the vapour can therefore reach the middle ear only when the tube is permeable. In cases in which the tube is greatly swollen, the simple or double air-bag is insufficient, and we are therefore

FIG. 94.—ELASTIC TYMPANIC CATHETER.

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* *Traité du cathétérisme de la trompe d'Eustache*, p. 53.
† *Traité théorique et pratique des maladies de l'oreille*, 1860, p. 77.

compelled to resort to air-pressure. The vapours enter the tympanic cavity more freely when the membrana tympani is perforated.

The temperature of the vapour varies according to the nature of the medicament employed, and according to the temperature at which it volatilizes.

The duration of the application likewise depends on the nature of the drug and on the irritation developed in the ear or pharynx. The time of application generally varies from three to ten minutes.

The introduction of vapours into the middle ear is accompanied by a feeling of warmth and fulness. Great burning or pain associated with injection of the vessels along the manubrium occurs most frequently after the action of ammonium vapours. The escape of the vapours into the naso-pharynx often causes great retching, hawking, coughing, congestion and swelling of the mucous membrane, and increased secretion.

It is now universally acknowledged that a smaller quantity of vapour introduced through the catheter reaches the middle ear than was formerly supposed. Large quantities, however, may reach the tympanic cavity when the tube is permeable. On the other hand, the subtle vapours of the various forms of ether, chloroform, and turpentine can easily be propelled into the middle ear.

3. The Author's Method for effecting the Permeability of the Eustachian Tube.

Politzer's Method.

This method of effecting the permeability of the Eustachian tube was published by the author in the year 1863.* It is based on the principle of condensing the air in the naso-pharynx during an act of swallowing, when this cavity is closed on all sides, and of forcing the condensed air through the Eustachian tube into the middle ear. The essential novelty of this method, by which it is differentiated from catheterization, lies in the fact that the nozzle of the instrument used for condensation of the air is introduced only into the anterior portion of the nasal cavity; the introduction of the catheter into the Eustachian tube, which is sometimes impracticable and often disagreeable, is thereby avoided. The closure of the naso-pharynx in this method is effected behind and below by the apposition of the soft palate to the posterior pharyngeal wall, and in front by compression of the alæ of the nose. The resistance in the tube is simultaneously lessened by the act of swallowing, whereby the influx of the condensed air into the tympanic cavity is considerably facilitated.†

* *Wiener med. Wochenschrift*, 1863, No. 6.

† The author's method was suggested by a number of manometric experiments made in reference to fluctuations in the air-pressure in the tympanic cavity. He quotes here the second experiment in reference to the above (*Wien. med. Wochenschr.*, 1863, No. 6), which he demonstrated to Professor v. Tröltsch in the year 1861: 'If I introduce the extremity of the escape-pipe of a force-pump half an inch into my nose, and compress the alæ around it, and then perform an act of swallowing while the compressed air rushes into the nasal cavity, I feel the air at the same moment entering with force into both tympanic cavities, whereby the drop of fluid in the manometer, inserted into the external meatus, moves outwards.'

To perform this method, the rubber bag used for catheterization (p. 119) is employed, the nozzle of which is shaped like a catheter; it is even better to arm the nozzle with a piece of resistant rubber tubing 3–4 cm. long (Löwenberg).

The technic of the method is as follows (Fig. 95): The patient, seated in a chair, takes a little water in his mouth, which he is requested to swallow when told,* and which is given to facilitate the act of swallowing. The physician, standing either in front or on the right of the patient, introduces with the left hand the curved nozzle of the Politzer bag, or the small rubber tube mentioned above, 1 cm. into the corresponding nasal orifice; care must be taken that the nozzle is inserted in the posterior angle of the nostril, and that the alæ of the nose are very closely compressed around it with the thumb and forefinger. The patient is then told to swallow, and at the same moment the air is expelled from the bag. The condensation of the air thus produced in the naso-pharynx forces the air into both middle ears; during the closure effected by the soft palate the tube is simultaneously opened, and its vibrations give rise to a dull, gurgling noise, which frequently, if not always, may be taken as an indication that the air has entered the tympanic cavity.

FIG. 95.—POLITZER'S METHOD.

The entrance of air into the middle ear gives rise to a subjective sensation in the majority of patients; still, this sensation may be entirely absent in a normal as well as an impaired sensibility of the mucous membrane of the middle ear. Children who suffer from a catarrh of the Eustachian tube often raise both hands to their ears at the moment when the air enters the cavum tympani (Pagenstecher). The bulging of the membrana tympani, as observed on inspection, is generally greater by this method than that produced by Valsalva's method, or by catheterization. The effect is most pronounced when the membrane is totally or partially retracted, inasmuch as the retracted parts

* The use of water is by no means necessary in all cases during the application of the author's method, as the effect of an inflation during an energetic act of deglutition is the same as that attained by the drinking of water. Sometimes, however, the simple act of swallowing is less powerful, and not only is the deglutition in such cases materially facilitated by drinking water, but the lumen of the tube is also more widened by the powerful contraction of the naso-pharyngeal muscles, and the effect of the injected air is thereby increased

are seen to bulge strongly outwards, and in cases of partial atrophy may sometimes protrude in the form of a bulla.

Auscultation during the application of the author's method shows that, even with an intact membrana tympani, the sounds produced in the middle ear are often plainly distinguished, in spite of the gurgling noises in the pharynx. By continued practice we are able to disregard the more distant pharyngeal noises, and to concentrate our attention upon those nearer to us in the middle ear. We also hear a noise produced by the bulging of the membrane and the abnormal auscultation sounds previously described in the section on catheterization. While during catheterization the noise appears modified by the friction of the air in the catheter, and by its escape from the point of the instrument, the auscultation sound during the author's method, where these obstacles are absent, is more clearly perceived, and tells us the exact condition of the middle ear. Where the tympanic membrane is perforated, the escape of air into the external auditory canal can be heard without the aid of the auscultation tube.

The air condensed in the naso-pharynx, as a rule, enters both tympanic cavities, but is generally forced more powerfully into that ear in which the resistance in the tube and in the tympanic cavity is less. In cases of unilateral affection, in which we wish to concentrate the effect of the inflation upon the diseased ear, and to limit as much as possible the entrance of air into the normal one, it is necessary to create an artificial resistance in the latter; this is accomplished by hermetically closing the external meatus of the normal ear with the finger. Similarly in bilateral affections we allow the patient to close the meatus of that ear in which, owing to the presence of a perforation or to a less resistance in the Eustachian tube, the air enters more freely: experience shows that the effect of the air-douche is thereby increased in the more diseased organ. Where both ears are affected, and the current of air enters equally strong in both, the mechanical as well as the therapeutic effect of the inflation can be increased by closing the meatuses alternately so as to allow the full power of the air-current to work upon both cavities.

The force of the air-current generally depends on the amount of resistance in the middle ear, on the presence of inflammatory phenomena, and on the pathological changes in the membrana tympani. Weak inflations are indicated in cases of slight obstacles where the hearing power is only slightly diminished, and also in acute inflammations of the middle ear where the reactive phenomena still continue. The gradual increase of the pressure can be regulated by using two, three, four, or five fingers successively; if we follow this latter method, we can introduce very weak or very strong currents into the middle ear as occasion requires. On the other hand, in cases of great resistance the permeability of the Eustachian tube must be effected by powerful

and rapid compressions of the air-bag. The air-pressure required in the execution of the author's method varies from 0·1–0·4 atmospheres and over.

The therapeutic effect of an air-douche after the author's method depends on the nature of the pathological changes which impair the function of hearing. In those affections of the middle ear in which a high degree of deafness exists in consequence of swelling and accumulation of secretion, combined with abnormal tension of the membrana tympani and ossicles, and also in those perforative middle-ear inflammations of not long standing, a striking improvement in the hearing will generally follow the application of Politzer's method. No improvement in hearing, or only one to a slight degree, is effected by the author's method in cases in which, in the course of inflammatory processes in the middle ear, new connective tissue has formed, thereby causing adhesions between the ossicles and the tympanic walls; furthermore, when the foot-plate of the stapes is fixed through a bony growth from the labyrinth capsule (Politzer) or in deafness of nervous origin. A subjective improvement in the hearing often corresponds with a demonstrable increase in the hearing distance, but cases are not infrequent in which the patient complains of a sensation of fulness in the ear after the application of the author's method, while the tests show that a considerable improvement in hearing has taken place.

The uncomfortable sensation of pressure in the region of the stomach which is sometimes experienced immediately after Politzerization occurs as the result of great pressure applied with compressed air, but very seldom follows the use of the air-bag. This sensation is caused by the sudden entrance of air into the inferior portion of the œsophagus, and may quickly be removed by several deep inspirations. Other sensations, occurring more rarely during the application of the author's method, are dizziness, fulness in the head, and headaches localized in the forehead. Ruptures of the membrana tympani, which occur during Valsalva's method and catheterization, are exceedingly rare in the application of the author's method, whether performed with an act of swallowing or during phonation. Ruptures occur most frequently in membranes which are atrophic, thinned by cicatrization, or contain deposits of chalk.* Such ruptures usually heal quickly, and, according to the observations of Pagenstecher, Schwartze, van Hoeck, Gradenigo, and the author (*Wien. med. Presse,* 1868), are not followed by bad results, but are usually accompanied by a noticeable improvement in hearing, which is often permanent. If one wishes to guard against rupture of an atrophic membrane during the use of the air-douche, it is advisable to close the external meatus with the finger.

In reference to the modifications of closing the soft palate, Schwartze† found that the air can enter the middle ears of children by applying the author's method without an act of swallowing. This can be explained partly by the narrowness of the naso-pharynx and shortness of the Eustachian tube, and partly by the fact that the soft palate is reflexly lifted by the action of the current of air on its superior surface; this causes the velum palati to be approximated to the posterior pharyngeal wall, thereby closing the inferior part of the naso-pharynx. Löwenberg‡ found that the act of swallowing during the author's method may be replaced in some cases by simply lifting the soft palate. The author observed that the condensed air entered the cavum tympani if the patients spoke the moment the air-bag was compressed.

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* The normal membrana tympani can be ruptured only by a pressure of 3–4 atmospheres (Schmiedekam). In practice, however, we seldom use a pressure exceeding ½ an atmosphere.

† Behrend's *Journal für Kinderkrankheiten,* 1864.

‡ *Centralblatt für die med. Wissenschaft,* 1865.

Czermak and Brücke experimentally demonstrated that the soft palate is approximated to the posterior pharyngeal wall during the phonation of vowels and consonants. Accordingly, Lucae (*Virch. Arch.*, vol. lxiv., 1875) proposed the substitution of the vowel *a* in place of the act of swallowing during the author's method. Following the suggestion of Lucae, Jos. Gruber proposed the syllables *hik* and *huk* in place of the vowel *a*. Experience has shown that all these changes, with few exceptions, are not new methods, but less valuable modifications for the closure of the soft palate, and are therefore, in the majority of cases, insufficient substitutes.

A very practical modification of the author's method, proposed by himself, consists in allowing the patient during the air-douche to take a deep inspiration through the slightly opened and pointed lips, or through a short rubber tube held between them (forced inspiration). By this means the naso-pharynx is closed, and the Eustachian tube is simultaneously widened by the downward traction of the soft palate. The therapeutic effect of this modification is, on the whole, inferior to the author's original method; cases, nevertheless, present themselves in which the air cannot be forced into the middle ear during an act of swallowing or during phonation, but enters freely by the modification with forced inspiration. Where the method with the act of swallowing is unsuccessful, we should always try the last-mentioned modification. The entrance of air into the cavum tympani is also facilitated during catheterization by a sharp inspiration through the mouth.

Another valuable modification (Holt) is the inflation of air into the middle ear while the cheeks are forcibly puffed out; the expiratory pressure thus produced forces the soft palate against the posterior pharyngeal wall, and, in this manner, the naso-pharynx is shut off from below. The inflation of air, according to this modification, is more often successful when the membrana tympani is perforated. The author has seen cases, however, in which it was applied with advantage in non-perforative middle-ear diseases, where the permeability of the tube could not be established by an act of swallowing or by phonation. The therapeutic value of this modification is, on the whole, inferior to that attained by an act of swallowing.

In reference to the practical value of the modifications as to the position of the soft palate during the application of the author's method, the act of simply blowing air into the naso-pharynx is of special value in children who cannot be induced to perform an act of swallowing. The air will enter the middle ear still more freely if the child cries during the inflation.* In giving an air-douche during the phonation of a vowel, the air very often fails to reach the middle ear, or enters only with a greatly diminished force, as the weak pharyngeal closure is easily opened by the current of air, and the resistance in the tube only slightly reduced. The same applies to the pronunciation of

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* According to Walb (*A. f. O.*, 1907), this method is also successful in children who do not cry, and is caused by irritation of the base of the tongue, whereby the soft palate is brought reflexly into apposition with the posterior pharyngeal wall.

the guttural consonants *hik, huk,* in spite of the fact that in this case the soft palate is pressed more closely against the posterior pharyngeal wall by the base of the tongue. The results are somewhat more favourable when single words are used during the application of the author's method. We can employ for this purpose such words as *König, Barique,* etc., by which the closure of the naso-pharynx is prolonged, and the air enters the middle ear more freely than when short syllables are used. In all these modifications, however, the air enters the middle ear far more seldom and with much less force than when inflating during an act of swallowing. Of all the movements of the muscles of the soft palate, there is none which exercises such an influence in opening the tube as the act of swallowing. This may be proved by the simple experiment, already described, of holding a vibrating tuning-fork (c^1) before the nostrils. If vowels or consonants are pronounced, there will be no noticeable change in the perception of the tone, but if an act of swallowing is performed, the tone will be heard markedly increased. The dilatation of the Eustachian tube during the application of the author's method with an act of swallowing is of the greatest practical importance; for in diseases of the middle ear, so often combined with marked resistance, in which only powerful currents of air are effective, the entrance of air into the middle ear is rendered possible chiefly by the material widening of the Eustachian tube during an act of swallowing,

Experience shows that in those cases in which the air cannot be propelled into the tympanic cavity by the phonation of vowels and consonants, a striking improvement in the hearing immediately follows if the author's method is applied during the act of swallowing. But even in those cases in which a certain increase in the hearing distance takes place after one or more inflations during phonation, a still greater improvement will generally follow the application of the author's method during an act of swallowing. As a rule, it is preferable to use Politzer's method during an act of swallowing, and only exceptionally is it advantageous to employ phonation, inspiration, or even expiration. The extensive use of phonation instead of an act of swallowing means the sacrifice of the therapeutic effect for the sake of convenience. Cases in which the air cannot be propelled into the middle ear by means of the author's method during an act of swallowing, but enters during phonation, are, on the whole, rare. Exceptionally, a similar action is also seen with the Valsalvan method, but, in spite of this fact, we are familiar with its inferior therapeutic value.

Excessive swelling and stenosis of the pharyngeal orifice of the Eustachian tube, and the occlusion of the latter with a tenacious plug of mucus, are the most frequent causes of air not entering the middle ear during the application of the author's method. Roosa was able to force air into the middle ear in such cases after he had previously washed out the naso-pharynx. The author often found with hindrances of this nature that his method, performed during an act of swallowing, was only then effective after several unsuccessful attempts had been undertaken during forced expiration or inspiration, or during phonation, or when a long rubber tube had been inserted as far as the osteum pharyngeum tubæ (Gomperz). At times the author has been able to overcome the impermeability of the tube by the injection of a few drops of a 5 per cent. solution of cocaine,

The Therapeutic Value of Politzerization as compared with the Valsalvan Method and Catheterization.

In order to judge the therapeutic value of the different methods of inflation, it must be mentioned that the treatment of the middle-ear disease by means of the air-douche not only depends on the entrance of air into the middle ear, but that the beneficial

effects of such a treatment, apart from the amount of pressure employed, are principally due to the impact of the entering air. Experience shows that in middle-ear catarrhs a strong, rapid inflation produces a much more noticeable improvement in hearing than weak currents which are gradually increased. The greater the impact of the entering air, the more the membrana tympani and the chain of ossicles will be forced outwards; this is especially the case when they have become retracted through middle-ear inflammation. Accordingly, therefore, the improvement in hearing will be the more striking and lasting the nearer the ossicles are approximated to their normal position. That the therapeutic effect of the inflation depends on the impact of the air in the middle ear is shown by the fact that better results are generally obtained by repeated powerful inflations than by continuous currents with a constant high pressure as produced with the double air-bag or compressed air.

In comparing the effect produced by the method of Valsalva and the author's we have learned from experience that the former often fails partially or totally in catarrhs of the middle ear associated with swelling of the mucous membrane of the Eustachian tube. Under such conditions, it will also be seen that the air enters the middle ear with greater force, and with a markedly increased therapeutic effect, when the author's method is employed. From a therapeutic standpoint, therefore, Valsalva's method is far inferior to Politzer's.

Besides this, Politzerization has the advantage over the Valsalvan method in that the congestion of the vessels of the head, which occurs during the latter, is avoided. There can be absolutely no doubt that this venous congestion, caused by a forced Valsalvan experiment, extends to the ears, inasmuch as we frequently observe injection of the vessels of the membrana tympani during a forced expiration. The frequent repetition of such a congestion will necessarily create a permanent hyperæmia in the ear, by which not only the inflammatory process already existing there is increased, but disturbances of circulation are also produced in the labyrinth. In the application of the author's method, however, congestion of the cranial vessels is completely avoided, as no action of the muscles of the thorax is required.

Comparing the value of Politzerization with catheterization, it must be mentioned that the current of air passing through the catheter cannot exert its full force on the middle ear, because the ostium pharyngeum tubæ does not completely surround the opening of the instrument, and thus allows a partial reflux of air into the pharynx. Furthermore, the marked friction of the air in the catheter causes it to leave the instrument with a greatly reduced force. We must also not lose sight of the fact that the point of the catheter is generally directed more towards the walls of the tube than towards its lumen, and the strength of the

current of air is thereby broken, and its effect on the cavum tympani weakened.

These disadvantages are partially overcome by the author's method; for the air, forced with a strong impulse into the Eustachian tube from the pharynx, exerts an almost equal pressure in all directions, and will therefore frequently enter the middle ear with greater certainty and with a more pronounced effect than during catheterization. Observations have also shown that, in many cases in which only a moderate increase in the hearing was noticed after catheterization, a striking improvement took place when the air was propelled into the middle ear by the author's method.

On the other hand, cases are observed in which the air cannot be forced into the middle ear by the author's method, while this is successfully accomplished by catheterization. These favourable results of catheterization are especially noticeable in those middle-ear affections in which the larger portion of the tube, from the ostium pharyngeum to the isthmus, is closed by excessive swelling of the mucous membrane. In such cases, the adherent walls are forced apart for some distance by the beak of the catheter, and the resistance in the upper portion of the tube is overcome by the current of air directed immediately against it. It is self-evident that catheterization is superior to Politzerization in cases of defect of the palate, in paralysis of the palatine muscles, and in other anomalies of the naso-pharynx which impair the act of swallowing.

If the therapeutic effect of the author's method is at times inferior to that attained by catheterization, it is nevertheless often superior, and possesses still other noteworthy advantages. They are:

1. The simplicity of its application, which enables the practitioner who is not familiar with catheterization to restore, in many cases, the permeability of the Eustachian tube, and to treat a number of affections of the middle ear successfully.

2. The possibility of injecting air into the middle ear as a therapeutic agent in many cases in which catheterization is impossible or meets with marked resistance. This is especially the case in children who suffer from a high degree of deafness in consequence of acute and chronic naso-pharyngeal catarrhs, or in those who have catarrhs of the tubes and middle ears owing to the presence of adenoid vegetations and hypertrophied tonsils. Politzerization can also be applied in the congenital and acquired deformities and diseases of the naso-pharynx (*vide* p. 114) which prevent the introduction of the catheter. Even when the nasal cavity is normal, it should be exclusively employed for restoring the permeability of the Eustachian tube in those persons who object to the introduction of the catheter, in nervous individuals, in aged people, and, lastly, in convalescents in whom it is urgent

to effect the permeability of the Eustachian tube on account of the accumulation of secretion in the middle ear, and because catheterization is impossible owing to the weakness and irritability of the patient. It is evident, therefore, that the author's method should be employed in all those cases in which catheterization can be dispensed with. When it is indicated to effect the permeability of the tube by a current of air, Politzerization is always preferable to catheterization, because the unpleasant sensations accompanying the latter are avoided; furthermore, the local irritation of the tubal mucous membrane produced by the catheter does not take place, and, finally, the permeability of both Eustachian tubes can be effected simultaneously. It must be stated most emphatically that it frequently happens that catheterization cannot be replaced by any other method as a diagnostic and therapeutic measure. This is especially true if the catheter serves the purpose of a conducting tube for the injection of fluids and for the introduction of bougies.

3. Politzerization possesses still another advantage in that it is well adapted for self-treatment by reason of its easy application. This applies especially to those chronic middle-ear affections in which, after treatment by the physician has ceased, inflations are necessary from time to time in order to maintain the improvement in hearing and to prevent a relapse.

In order to inject small quantities of fluid into the middle ear by the author's method when the membrana tympani is intact or perforated, the following procedure is recommended: The patient takes a little water in his mouth and bends the head slightly towards the affected side; thereupon warm sterilized fluid is injected through the nostril with a Pravaz syringe, and is immediately followed by an inflation of air, according to the author's method. By observing the above-mentioned precautions, a painful reaction after these injections is seldom brought about. In cases in which this nevertheless does occur, the pain disappears rapidly if Politzerization is performed with the head of the patient inclined forwards and to the opposite side, or if the external meatus is filled with warm water.

Politzerization may be used in perforations of the membrane to wash out secretion from the middle ear, and to irrigate this cavity with medicated fluids. It is performed as follows: After the patient has taken a little water into his mouth and bent the head to the side opposite the diseased ear, the external meatus is filled with warm peroxide or a warm medicated solution, and with the head in this position repeated forcible inflations, according to the author's method, are given. This manipulation causes the air to escape from the external meatus in the form of large bubbles, whereby the tympanic cavity is not only cleansed, but the entrance of the medicated fluids into the middle ear is greatly facilitated.

THE METHODS OF EXAMINATION AND TREAT-
MENT OF THE MIDDLE EAR THROUGH
THE EXTERNAL AUDITORY CANAL.

The Rarefaction and Condensation of Air in the External Auditory Canal.

The method of aspirating air from the external auditory canal, introduced in the eleventh century by a physician named Simeon* and in the eighteenth century by Archibald Cleland, became obsolete after a number of years.† Both authors reported remarkable improvement in hearing in a number of cases. It was only in the middle of the nineteenth century that Moos and v. Tröltsch again recommended the rarefaction of the air in the external auditory canal as a therapeutic agent.

In the last decade, greater attention has been paid to the therapeutic value of the variations of air-pressure produced by artificial means in the external meatus, and the effect of air condensation, and its combination with rarefaction, have also been more fully investigated.

Chas. Delstanche deserves the credit of having introduced this last-mentioned method into practice as the so-called massage of the drum membrane and ossicles.

The therapeutic effect of inflations into the middle ear can be increased in many cases by rarefying the air in the external auditory canal. By aspirating the air in the external meatus, the membrane, so frequently abnormally retracted and tense in middle-ear affections, is drawn outwards with the chain of ossicles into a nearly normal position, thus increasing the vibratory function of the sound-conducting apparatus. The increased labyrinthine pressure is simultaneously diminished by the outward movement of the foot-plate of the stapes from its attachment in the fenestra ovalis. Condensation of air in the external auditory canal is seldom used alone as a therapeutic agent; it is more often employed in combination with rarefaction in an alternating manner, and is known as ' massage ' of the drum membrane and ossicles (Delstanche). This procedure is especially applicable in otosclerosis, and in adhesive processes of the middle ear, which are associated with rigidity of the joints of the ossicles.

The Rarefaction of Air in the External Auditory Canal.

The author used the masseur invented by Chas. Delstanche for the rarefaction of air in the external auditory canal. During the last few years, however, this instrument has become more

* Cp. Politzer, *Ges. d. Ohren.*, vol. i., p. 61.

† See *Comment. zu Boerhave's Aphorism*, tom. ii., 1805, p. 677, remarks by van Swieten.

or less obsolete owing to the introduction of more practical electrical appliances. In place of the Delstanche masseur, we now give the pneumo-massage with a small pump, which is driven by an electric motor, and to which there is attached a small appliance whereby one can use either rarefied or condensed air, or both together. This pneumo-massage exercises its beneficial effects by alternately condensing and rarefying the air in the external auditory canal, and by a screw arrangement on the pump one is able to increase or decrease the air-pressure as occasion demands. In the absence of a masseur, one can use either a Siegle's speculum or a rubber tube 30 cm. long, which is hermetically inserted into the meatus by means of an olive-shaped tip, the free end of which is connected with a small powerful air-bag (No. 3). The aspiration is accomplished in the following manner: The air-bag is first compressed, the olive-shaped tip is then hermetically introduced into the external meatus, and the air-bag allowed to expand slowly. This procedure may be repeated four or five times at one sitting.

In carrying out the various methods of rarefaction, it is important that the aspiration is not performed too rapidly, as a painful tearing of the bloodvessels may occur in the meatus and on the membrane; it is even possible to cause a rupture of the latter.

Rarefaction of air in the external auditory canal is used—

A. **For Diagnostic Purposes** :

1. It renders, with the aid of Siegle's speculum, a means by which we are able to ascertain the exact amount of excursion, the degree of tension, and the resistance of the various parts of the membrane, and to diagnose its partial or complete adhesion with the inner tympanic wall.

2. To locate perforations in those cases in which the borders of the aperture lie in contact, and are recognized only by the appearance of secretion at a certain spot on the drum during aspiration.

3. To diagnose localized suppurative processes in the middle ear, especially in the attic and antrum.

4. To diagnose polypoid growths in the attic and antrum.

5. To diagnose extradural abscesses (*vide* special chapter).

B. **For Therapeutic Purposes** :

1. In all catarrhs of the cavum tympani and Eustachian tube in which the membrana tympani is retracted, but only after the tube has been made permeable by an inflation of air.

2. In adhesions between the membrana tympani and inner tympanic wall.

3. After paracentesis of the membrane, in order to aspirate serous, mucous, or purulent exudates from the cavum tympani into the external auditory canal.

4. To aspirate pus from the cavum tympani into the external meatus (E. Polizter, Gruber) in chronic middle-ear suppurations,

but only after an inflation has been given; furthermore, in cases in which the injection of air through the Eustachian tube is impossible, or in which no beneficial result is obtained; and, lastly, in localized suppurations of the cavum tympani which do not communicate with the tube.

5. In subjective noises in the ear, which often cease either entirely or become less troublesome. Besides this, it often produces a noticeable subjective relief in the ear and head, which renders this method of special value in the treatment of middle-ear catarrhs.

6. To relieve dizziness and attacks of vertigo brought about by an increased labyrinthine pressure, which is produced either by diseased products in the middle ear or by a pathological process in the labyrinth itself. Attacks of vertigo caused by syringing when there is a perforation of the membrana tympani, or by other manipulations in the ear, may be quickly relieved by rarefaction. Delstanche succeeded in curing a case of sudden deafness, following an explosion, by treatment with his *rarefacteur ;* Goris and Lecocq reported the cessation of epileptic attacks by the use of the same instrument (*epilepsia ex aure lœsa*).

The Condensation of Air in the External Auditory Canal.

The condensation of the air in the external auditory canal is used less often than rarefaction in non-perforative middle-ear diseases. On the other hand, in a number of cases in which a perforation of the membrane exists, good results are obtained by condensation (Lucae). It is best accomplished with Delstanche's masseur or with the electric pneumo-massage previously described. By this procedure, the compressed air is forced through the tube into the naso-pharynx, and may be distinctly heard as a rattling noise; if there is no secretion in the middle ear, however, the air may escape with a dry, snapping sound.

Condensation of air in the external meatus is used—

I. **For Diagnostic Purposes :**

To establish the presence of a perforation in cases in which the aperture in the membrane is invisible, and in which an inflation gives a negative result. If one end of the auscultation tube is placed in the nostril of the patient, while the other end is inserted into the ear of the physician, the air, escaping into the pharynx, will be plainly heard every time it is condensed in the external meatus. During this procedure, the patient must breathe quietly through the mouth in order to avoid the disturbing sounds of respiration (method of the author).

II. **For Therapeutic Purposes :**

(*a*) In perforation of the membrana tympani, to remove the secretion from the middle ear in cases in which neither the air-

douche nor rarefaction of the air in the external meatus succeeds in expelling it. The secretion is thus forced into the naso-pharynx from the Eustachian tube, and only from the anterior portion of the cavum tympani. During this manipulation, great pressure is to be avoided, as it may easily cause attacks of vertigo.

(*b*) After paracentesis of the membrana tympani, where it is desired to force tenacious masses of mucus through the tube into the pharynx, because their removal is rendered difficult through the artificial opening.

(*c*) In dry perforations, to make the tube permeable when it cannot be accomplished by an inflation of air. This procedure must be undertaken with great precaution, and must be im-mediately interrupted if dizziness occurs (compare contra-indications).

(*d*) To irrigate the tympanic cavity from the external meatus when this is impossible through the tube or by the author's method. The manner of performing this operation is as follows: After the middle ear has been cleared of secretion by means of an air-douche and syringing, the external meatus is filled with warm water. The olive-shaped tip of the tube is then tightly inserted into the external orifice of the ear, and the water driven through the tube into the pharynx by compressing the air-bag. Where it is desired to use a larger quantity of warm water, a large syringe or an air-bag syringe (No. 8) may be employed, both of which are provided with an olive-shaped tip. This procedure, proposed by the author, has been very serviceable in several obstinate cases of middle-ear suppuration in which other methods have failed.

(*e*) In certain forms of deafness resulting from catarrhs of the middle ear (Delstanche, *vide* special chapter).

(*f*) To alleviate subjective noises which are neither diminished by the air-douche nor by the rarefaction of the air in the external meatus.

Condensation of the air in the external meatus is contra-indicated when the membrane is retracted, and, furthermore, if a perforation of the membrane is associated with such a resistance in the tube that the air will not pass by the author's method. In such cases, great dizziness, ringing in the ears, and deafness are often produced by the increased labyrinthine pressure. These unpleasant symptoms are most easily alleviated by immediately aspirating the air from the external meatus.

From the foregoing, it is evident that the method of rarefaction and con-densation of air in the external meatus must always be regarded only as a supplement, and in many cases as a partial substitute for those methods which serve to bring about the permeability of the Eustachian tube.

The Rarefaction and Condensation of the Air in the External Auditory Canal.

The alternate application of these two methods, performed in rapid succession, was introduced into practice by Delstanche as massage of the membrana tympani and ossicles. It produces an increased mobility of the ossicular chain, which has become lessened, partly through rigidity of its joints and partly through adhesions between the membrana tympani, ossicles, and tympanic walls. This method is therefore especially applicable in adhesive processes of the middle ear and in otosclerosis.

For pneumo-massage of the membrane, we employ either Delstanche's masseur, Siegle's speculum, or a small air-bag (No. 3), to which is attached a piece of rubber tubing and an olive-shaped tip, which fits into the external auditory orifice. In the last few years, electro-motor apparatus have been constructed by various manufacturers of electrical appliances, to which the masseur of Delstanche is attached and set into motion by the electric current. By means of these apparatus the variations of air-pressure in the auditory canal can be increased or diminished at will. In some cases, the therapeutic effect derived from these apparatus excels that obtained by Delstanche's masseur while in other cases the latter is more serviceable.

As a rule, massage is commenced with aspiration, which is followed by compression. The duration of the application—that is, the number of oscillatory movements—depends on the anatomical cause disturbing the function of hearing. It varies from five to ten minutes. The greater the disturbance of hearing, the longer the massage can be applied. Sometimes, as in many cases of sclerosis, short, quick strokes, following in rapid succession, prove more beneficial than slow, forcible aspirations and compressions.

In applying massage, the intensity of the air-pressure is regulated by the degree of obstruction in the sound-conducting apparatus. The greater the disturbance of hearing, the greater must be the pressure applied. In middle-ear diseases accompanied by a slight disturbance of hearing, violent massage causes a feeling of pain, sometimes dizziness and increased tinnitus, while in diseases accompanied by a marked disturbance of hearing, massage of the same pressure produces hardly any unpleasant symptoms. Accordingly, in each case, we gradually increase the aspiration and condensation, as we must take into consideration the above-mentioned subjective sensations of the patient. When pain is experienced, we must lessen the pressure.

Pneumo-massage occasions, in many cases, not only a decided improvement in hearing, but also a momentary, temporary or permanent diminution in the subjective noises. It exercises a decidedly beneficial effect upon the head symptoms, such as heaviness, feeling of fulness, deafness, etc., which usually accompany affections of the ear, and which are not infrequently entirely

cured by this method of treatment. Sometimes, however, one observes an increase in the subjective noises, dizziness, and a diminution of the power of hearing, even after a short application of the massage. Pneumo-massage is contra-indicated in inflammatory affections of the middle ear, and in primary, uncomplicated diseases of the sound-perceiving apparatus (Ostmann).

Lucae recommends a probe, containing a small spring, for the immediate massage of the ossicles; its hollowed point is covered with a small piece of rubber, and is placed against the processus brevis. By repeated, gentle tappings with this sound on the short process of the malleus, the chain of ossicles is mobilized, and thus in adhesive processes of the middle ear an increase in the hearing of a varying degree is obtained. This method is often very painful, even if the instrument is carefully manipulated, but is sometimes well endured after repeated applications. König uses a sound of this nature for massage, the end of which is covered with paraffin. Besides Lucae, Jacobson and Walb also report very good results from the application of this sound. According to the author's observations, this method of treatment does not, on the whole, give better results than pneumo-massage. In a few cases, however, a greater increase in the hearing is observed after the use of this sound; still, there are cases in which its application produces a decided change for the worse.

C. The Tests for Hearing.

The tests for hearing hold an important place in otology as a means of diagnosis. They not only aid in determining the degree of impairment of hearing, but also in localizing the pathological changes. When the other methods of examination give a negative result, we are enabled by these tests to determine whether the cause of the disturbance of hearing has its seat in the sound-conducting or in the sound-perceiving apparatus. These tests are still further of special value, as it is only through them that we are in a position to note the result of treatment.

In using the tests for hearing as a means of diagnosis, we must examine the power of perception for the waves of sound transmitted through the air to the membrana tympani, as well as the sound perception through the cranial bones.

A. Testing the Power of Perception for the Waves of Sound transmitted through the Air to the Membrana Tympani.

I. Testing the Acuteness of Hearing for Simple Tones.

(a) Testing the Acuteness of Perception for the Watch and Acoumeter.

The watch, tuning-fork, and speech, which were formerly our only aids in testing, proved insufficient as means of ascertaining the exact condition of the function of hearing in diseases of the ear.

In testing the acuteness of hearing for simple tones, we still frequently use the ordinary watch or a stop-watch. As all watches differ considerably in the pitch and intensity of their tone, it is evident that the results vary greatly when testing with different instruments. They are therefore not suitable in enabling us to obtain a precise knowledge of the acuteness of hearing.

These imperfections induced the author to construct an acoumeter, having a fixed tone, and intended to replace the watch in the tests for hearing.

Each ear must be examined separately. During the examination of one ear, the meatus of the other must be closed as tightly as possible with the moistened finger. The hearing distance is ascertained by gradually bringing the instrument nearer to the ear of the patient until the strokes of the watch or acoumeter are distinctly audible. To avoid errors in diagnosis, the patient is requested to cover the eye of the same side with the corresponding hand, so that he cannot see the place from whence the sound originates.

In order to properly judge the value of the tests for hearing, it must be stated that the acuteness of sound perception is subject to great variations, not only on different days, but also at different times of the same day. It may even vary within a very short time, and is also influenced by the temperature and humidity of the atmosphere, and by somatic and psychical conditions. It is self-evident that the sounds and noises occurring during the day influence the results of the tests.

The acuteness of hearing for the acoumeter, or for the watch, frequently shows marked differences, according to whether the instrument is approximated to the ear from without the boundary of perception, or whether it is removed from the ear after the sound has been perceived. In the latter case, the hearing distance is almost always greater than in the former. The cause of this, in the author's opinion, lies in the fact that when the sound, which has not yet been heard, is brought near to the ear, the endings of the auditory nerve, which are at rest, require a greater stimulus to disturb their equilibrium. Accordingly, the origin of the sound must be brought nearer to the ear in order to irritate the auditory nerve. On the other hand, when the already perceptible sound is withdrawn from the ear, the auditory nerve is in a state of irritation, and is kept in this condition by vibrations of lesser intensity, so that the sound is perceived at a greater distance.

The average normal hearing distance for the acoumeter is 15 m. Hartmann, Chimani and the author obtained this result by tests which were carried out in rooms as noiseless as possible, and on individuals with normal hearing. Therefore, according to Knapp and Prout,[*] the relative hearing power for 1 m. is $\frac{1}{15}$, for 10 cm. $\frac{0.1}{15}$, and for 3 cm. $\frac{0.03}{15}$. As 15 m. is supposed to be the normal hearing distance for the acoumeter, these fractions

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[*] *A. f. O.*, vol. xiii.; *A. f. Augen- u. Ohrenheilk.*, vol. vi.

express the relative hearing distance in diseased conditions. Bezold and the author noticed that when there is an increase in the hearing distance for the acoumeter, it may be concluded, with great probability, that there will be a corresponding increase in the perception for speech; but, on the other hand, if the hearing distance is increased for the watch, there need not be a corresponding increase in the perception for speech. Still, cases are frequently met with in which a great disproportion exists between the hearing distance for the acoumeter and that for speech. Therefore, testing with the acoumeter (or watch) has only a relative value. This method of testing is especially advantageous in those cases in which we wish to diagnose a slight degree of deafness which can scarcely be detected in ordinary conversation, or even when testing with whispered speech; such disturbances of hearing can be discovered, however, by testing with the weak sounds of the acoumeter or of the watch. In a like manner, we may conclude that there is an improvement in the hearing distance for speech if, during the treatment, the tick of the watch or acoumeter is again heard, or is perceived at a much greater distance than in the beginning of treatment.

(b) Testing the Perception for Musical Tones conducted through the Air.

The devices used by the specialist for this purpose are: A series of tuning-forks, different high-pitched whistles, a series of König's steel cylinders, and musical instruments.

Tuning-forks.[*]—Examination with the tuning-fork plays an important part in testing the hearing. Great progress has been made in the last few years in the differential diagnosis of middle-ear and labyrinthine affections by the combined method of examining the conduction of sound through the cranial bones and through the air by means of high and low tuning-forks.

The practitioner requires at least three tuning-forks (c, c¹, and c⁴), for diagnostic purposes and for testing the perception for the upper, middle, and lower tones.

[*] As in most text-books the number of vibrations for the different tones is not correctly given, the author adds a table from Appunn, in which the number of vibrations for the pure tones is given:

$C^{.2}=32$	$D^{.2}=36$	$E^{.2}=40$	$F^{.2}=42_{.66}$	$G^{.2}=48$	$A^{.2}=53_{.33}$	$H^{.2}=60$
$C^{.1}=64$	$D^{.1}=72$	$E^{.1}=80$	$F^{.1}=85_{.33}$	$G^{.1}=96$	$A^{.1}=106_{.66}$	$H^{.1}=120$
$c=128$	$d=144$	$e=160$	$f=170_{.66}$	$g=192$	$a=213_{.33}$	$h=240$
$c^1=256$	$d^1=288$	$e^1=320$	$f^1=341_{.32}$	$g^1=384$	$a^1=160_{.66}$	$h^1=480$
$c^2=512$	$d^2=576$	$e^2=640$	$f^2=682_{.64}$	$g^2=768$	$a^2=853_{.32}$	$h^2=960$
$c^3=1024$	$d^3=1152$	$e^3=1280$	$f^3=1365_{.12}$	$g^3=1536$	$a^3=1706_{.64}$	$h^3=1920$
$c^4=2048$	$d^4=2304$	$e^4=2560$	$f^4=2730_{.26}$	$g^4=3072$	$a^4=3413_{.28}$	$h^4=3840$
$c^5=4096$	$d^5=4608$	$e^5=5120$	$f^5=5461_{.12}$	$g^5=6144$	$a^5=6826_{.56}$	$h^5=7680$
$c^6=8192$	$d^6=9216$	$e^6=10240$	$f^6=10922_{.24}$	$g^6=12288$	$a^6=13653_{.12}$	$h^6=15360$
$c^7=16384$	$d^7=18432$	$e^7=20480$	$f^7=21844_{.14}$	$g^7=24576$	$a^7=27306_{.24}$	$h^7=30720$

While some employ for diagnostic purposes a complete octave series, C.¹ to c⁷, in all nine tuning-forks, Bezold recommends the continuous range of forks constructed by Edelmann. This comprises ten tuning-forks, two pipes, and a Galton's whistle. These forks are supplied with movable weights, and can thus be tuned for a varying range of tones. Accordingly, Bezold's tuning-forks take in the entire scale of the human organ of hearing from *sub contra* C, with sixteen double vibrations, to the highest perceptible tones.

This complicated arrangement is of value for the discovery of gaps in the scale which often occur in deaf-mutes, less often in diseases of the ear, and, furthermore, to determine the range of hearing in deaf-mutes.

Apart from the vast amount of time required in the manipulation of this method, it is superfluous for a differential diagnosis of middle-ear and labyrinthine affections, as the same result can be obtained with a smaller number of tuning-forks. Hartmann recommends a series of five tuning-forks; Dennert advises the use of c or c¹, c³-c⁵; Panse, e²-e⁸; Bonnier, a tuning-fork with exactly 100 double vibrations; Lucae, a small English tuning-fork, which is provided with a scale and movable clamps; if the position of the latter is changed, a rise of tone, encompassing an octave, can be produced.

Testing the Perception for the Tuning-fork by Conduction through the Air.—In carrying out this test, we first determine the decrease in the hearing distance in the diseased as compared with the normal ear. The method of ascertaining the acuteness of hearing, according to the time the vibrations of the tuning-fork are heard, was introduced by Conta.* For this purpose, the most serviceable instrument is a König c¹ tuning-fork (256 V.= König's ut²=512 double vibrations), which is put into vibration by gently striking one of the prongs against the palm of the left hand. It is desirable to use, as near as possible, the same force at every stroke. It is then held before the ear of the patient until he states that he no longer hears the sound. The tuning-fork is then brought to our own ear (or, if we are dealing with a unilateral affection, to the normal ear of the patient), and the difference in time is noted between the perception of the diseased and the normal ear. This method, however, is by no means precise, as the difference in time between the perception of the diseased and the normal ear shows great variations if the tests are often repeated. The results of this method of testing are seldom in proportion to the degree of deafness for speech. We can, nevertheless, always employ it, in conjunction with the other methods of examination, to ascertain whether there is an increase in the hearing during treatment—in other words, to determine the improvement in the hearing, or the reverse, at a later examination.

If we wish, in bilateral affections, to establish the qualitative difference in the perception of the two ears, the vibrating tuning-fork (c¹) is changed from one ear to the other at short intervals, and held at about the same distance from both ears; the patient

* *Arch. f. Ohrenh.*, vol. i., p. 107.

is then asked in which ear the tone is better perceived. The tone of the tuning-fork will generally be more faintly perceived by that ear which is diseased; the opposite is seldom the case. In slight disturbances of hearing, the difference in perception between the two ears must be tested with very weak vibrations, and the difference in time noted. By this method of testing, one not infrequently observes, especially in unilateral middle-ear affections with increased tension of the sound-conducting apparatus, that the tone of the tuning-fork is perceived one-quarter, one-half, sometimes even a whole tone higher in the diseased ear; it seldom happens, however, that the reverse is the case—in other words, that the tone is perceived lower in the affected ear.

Testing the Perception for High and Low Tones conducted through the Air.—This method of testing has recently attained an importance which must not be undervalued in the differential diagnosis of middle-ear and labyrinthine affections. In an exhaustive paper published by the author in the year 1871 (*A. f. O.*, vol. vi.), he showed, by experiments on the cadaver, that high tones are, as a rule, heard better than low ones in obstructions in the sound-conducting apparatus. These experiments were carried out for the purpose of testing high and low tones for diagnostic purposes. Lucae first called attention to the diagnostic value of testing with low-toned tuning-forks. He found that the low-toned tuning-fork was either heard faintly or not at all in middle-ear affections in which the hearing power for speech was greatly decreased; and, on the other hand, that the same tone was still well perceived in labyrinthine affections, even where a high degree of deafness existed. From the foregoing, according to Bezold, the sound-conducting apparatus participates only in conducting low tones, and is unnecessary for the conduction of high ones. The failure to perceive low tones is therefore very important in the diagnosis of obstructions in the sound-conducting apparatus.

Clinical observation shows that high tones are generally perceived better in obstructions in the sound-conducting apparatus, and that low tones are heard better in diseased conditions of the auditory nerve. This method of examination is of diagnostic value only when taken in conjunction with the other tests. According to what has been detailed above, we can state that low-toned tuning-forks are of the greatest assistance in diagnosing an obstruction in the sound-conducting apparatus, as in such cases it is exceptional for the deep tones to be perceived. Testing with high tones, however, is less reliable, because in middle-ear affections in which the hearing is greatly diminished the perception for these tones may also be lacking. On the other hand, again the perception for the low tones may be entirely absent when the auditory nerve is effected,

while, according to the author's observations, the high tones are rather often distinctly audible to the highest limit of perception.

In testing the perception for low tones, the tuning-fork c (128 V.) is sufficient for most cases; still, it is sometimes necessary to use the C-^{1} (64 V.). Politzer found that the vibrations of these forks were perceived as a sensation of touch by the auricle and membrana tympani in a great number of cases in which the disturbance of hearing was due to an obstruction in the sound-conducting apparatus. These sensations were interpreted by the patients as sounds, which could not have possibly been the case, as they could not even hear the higher tones of the next tuning-fork above. In testing the perception for high tones, we use the c^4 (2048 V.) or c^5 (4096 V.) tuning-fork; lastly, to test the uppermost limit of the scale, we employ Galton's whistle, introduced into practice by Burkhardt-Merian (1878) and perfected by Edelmann.

Galton's whistle consists of a small, covered, cylindrical tube which can be lengthened and shortened by a movable piston. The inferior part of the piston is in connection with a hollow cylinder which glides over the cylinder of the whistle. On the latter there is a longitudinal scale marked off in ' tens,' while on the former there is a scale around its inferior margin to read off the single numbers. By compressing a small rubber bag attached to its inferior extremity, the instrument is made to produce its tone (whistle).

According to Burkhardt-Merian, the Galton whistle takes in more than the three upper octaves of the scale, the tones of which have 6,481–84,000 simple vibrations per second. This instrument is therefore suitable for ascertaining the power of perception for the highest tones. Although our uppermost range of perception for the whistle ceases at 40,000 V., we are nevertheless aware that there are still higher vibrations, as-is proved by the quivering of a sensitive gas-flame.

In case of necessity, musical instruments such as a piano or harmonica can also be used to test the perception of low and high tones.

Testing with high-pitched tuning-forks and Galton's whistle is of value only in bilateral affections, and in cases in which the disturbance in hearing is far advanced. In unilateral affections, the results of testing are unreliable, as the perception for the higher tones cannot be excluded in spite of hermetically closing the normal ear. The same applies to bilateral affections in which the one ear is only slightly affected. In some cases, we can localize the perception of sound in the diseased ear by conducting the tones into the auditory canal by means of a long ear-trumpet.

The perception for high tones, especially those of Galton's whistle, decreases in old age mainly as a result of retrogressive changes in the labyrinth (Zwaardemaker). Inability to perceive the highest tones is physiological in some persons.

(c) Experiment of the Author to Test the Perception for the Tone of the Tuning-fork through the Eustachian Tube.

This experiment, first performed by the author (p. 59), consists in holding a vibrating c^1 tuning-fork (256 V.*) in front of the nostrils, whereupon its tone is more strongly perceived in both ears during an act of swallowing. It can be used as a means of diagnosis in a number of cases: (1) To ascertain the permeability of the Eustachian tube; (2) to establish the presence of an obstruction in the sound-conducting apparatus. The results of this experiment are:

1. In unilateral middle-ear affections, associated with impermeability of the tube resulting from swelling of its mucous membrane or clogging with secretion, the tone of the tuning-fork c^1, when held before the nostrils, will be heard only in the normal ear in the majority of cases. If, in unilateral deafness. a diagnosis of middle-ear disease is made by the condition of the membrana tympani or by Weber's or Rinne's test, and the tone of the tuning-fork, held before the nostrils, is heard louder in the normal ear, we may conclude that the tube is impermeable on the diseased side.

If, in such cases, the permeability of the tube is established by catheterization or by the author's method, the tone of the tuning-fork held before the nostrils will be heard louder in the diseased ear; this may be either temporary or permanent. This symptom is a favourable prognostic sign, as we may conclude that the permeability of the tube can be restored.

2. In those unilateral middle-ear affections in which the Eustachian tube is permeable, a c^1 tuning-fork held before the nostrils will often be heard louder in the diseased ear (as in Weber's test). Exceptions to this rule are not rare. If, therefore, in unilateral deafness, an obstruction in the sound-conducting apparatus has been diagnosed by ocular inspection or by Weber's or Rinne's test, we may conclude that the tube of the diseased ear is permeable if the c^1 tuning-fork is perceived louder in this ear. This phenomenon occurs most frequently in unilateral chronic middle-ear catarrhs, and in otosclerosis; also in purulent middle-ear diseases, running their course with perforation of the membrana tympani, especially in cases in which the perforation is dry, and in which the swelling of the mucous membrane of the middle ear is slight.

In bilateral affections, in which one ear is decidedly more affected, this test seldom gives the result previously described.

3. In middle-ear suppurations which have run their course and are associated with a perforation of the membrane which fails to close, and also with cicatrices in the latter, the examiner can occasionally hear the sound of the tuning-fork greatly

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* High and low tuning-forks are not suitable for this experiment.

increased during this experiment by the aid of the auscultation tube. The same is also noticed if thin cicatrices are stretched before the tympanic orifice of the tube.

4. In unilateral labyrinthine affections, in which the objective examination and all the symptoms point to a diseased condition of the auditory nerve, the tone of the c^1 tuning-fork will be heard only in the normal ear when the tube is at rest, as well as during an act of swallowing.

2. TESTING THE HEARING FOR SPEECH.

Oscar Wolf, of Frankfort-on-the-Main,[*] deserves the credit, through many thorough investigations, of having established the keynote for the different sounds of speech, as well as the distances at which they could be distinguished.

According to this author, speech has a compass of eight octaves, from C^{-2} to c^5. The lowest tone is R lingual, the highest S. He calls the following self-toned: The loud R lingual, B, K, T, F, S, Sch, and G soft. On the other hand, the following borrow their tones: L, M, N, and W. The self-sounding letters possess, according to Wolf, a definite, intrinsic tone, while those which borrow their sound have no definite tone of their own.

In fixing the hearing distance for speech with a view of estimating the amount of disturbance of hearing, many difficulties are met with. Attention must be called to the fact that the vowels are perceptible at a greater distance than the consonants, owing to the strength of their tone and the greater amplitude of their vibrations.[†] It is for this reason that patients frequently hear only the vowels of a word of several syllables, and change the consonants, and when repeating what they have heard pronounce another word which contains the same vowels, but different consonants; for example, in using the word ' garter,' they repeat ' garden '; for ' marble,' ' gargle '; for ' grocer,' ' broker,' etc. It is also observed that those words in which the vowels *a*, *e*, and *i* occur are more easily perceived, and at a greater distance, than those which contain the vowels *o* and *u*. It must still be added that the self-toned consonants are heard with more difficulty than those which borrow their sound. The power of comprehending different words at a fixed distance

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* *Sprache und Ohr: Acustisch-physiologische und pathologische Studien* (Braunschweig, 1871), and *Neue Untersuchungen über Hörprüfung und Hörstörungen; A. f. Augen und Ohrenheilk.*, vol. iii. *Ferner Hörprüfungsworte und ihr differentiell diagnostischer Werth. Zeitschrift f. Ohrenheilkunde*, vol. xx. *Die Hörprüfung mittlest der Sprache. Zeitschrift f. Ohrenheilkunde*, vol. xxxiv.

† Compare A. Politzer's experiments in reference to this (*A. f. O.*, vol. vi.), and this text-book, p. 60.

therefore depends on the manner in which the vowels and consonants are combined, and also on the rhythm and accentuation of the syllables.   For this reason, some words are understood at a disproportionately greater distance than others.

The difference in the volume and timbre of the voice in different individuals, both for ordinary conversation and whispered speech, is an important factor in testing the hearing for speech. Another important factor is the impossibility of always speaking with the same strength of voice, even with the most careful practice.   The results of testing the hearing for speech are therefore not of absolute, but only of relative, value.

The above test, in spite of its imperfections, must nevertheless be considered as indispensable in estimating the disturbance of hearing and the results of our treatment.   We have learned from experience that a striking disproportion often exists between the hearing distance for the watch (or acoumeter) and for speech, and that the hearing distance for the former not infrequently increases to a considerable extent during treatment, while the distance for the understanding of speech increases but slightly, and *vice versa*.   The degree of deafness for speech can therefore not be estimated from the results obtained by testing with a watch or other sound-producing instrument.   Since, in the treatment of disturbances of hearing, our endeavour is mainly centred in the re-establishment or improvement in the hearing power for speech, the latter therefore becomes indispensable as a means of testing.

To ascertain the hearing distance for speech (quantitative test, according to O. Wolf), we use ordinary conversation as well as whispered speech.   The result of the test is more certain when using the latter, as the ordinary volume of tone is diminished by the speaker, and the waves of sound reach the ear with much less intensity than when using loud speech.

In spite of the fact that, when testing with whispered speech, the differences in the hearing distances for certain words are less than when testing with loud speech, we must nevertheless always test with both where the room-space permits.   We employ both forms, as no positive relation exists between them, and the perception for whispering does not allow us to draw a conclusion as to the perception for conversation.   It is essential that we ascertain the hearing power for the latter, as it gives us an idea of the patient's power of perception for ordinary conversation. In severe forms of deafness only conversation speech can be used.

O. Wolf (*loc. cit.*) has presented a systematized scheme, in tablet form, of the tones of speech used in testing; in a second tablet, the distances at which they can still be distinctly differentiated.   According to this author, A is heard the furthest (280 m.), while mute H is heard at the shortest distance (10 m.).   Between these two extremes are the remaining tones of speech; of

these, the simple and combined vowels a, o, ei, e, i, eu, au, and u are per-
ceived at the greatest distance (288–224 m.), the consonants sch, m, n, s
(160–140 m.) f, k, t, r (55–35 m.), b, g, h (10 m.). These figures, obtained
by Wolf from his own tests, possess no absolute value, as the intensity of
whispered, and especially of ordinary, speech varies in different individuals.

The average normal hearing distance for whispered speech in a room as
noiseless as possible is, according to Chimani and O. Wolf, 20–21 m.; accord-
ing to Denker, 20–25 m.; according to Hartmann and Siebenmann, 25–26 m.
During the noise of the day, which often has a marked influence on the
perception for speech, it is 20 m. Jankau found the hearing distance to be
10–12 m. for words, and 14–15 m. for figures. According to Matte and
Schultes, figures from 1–99 should be understood at a distance of 45 m.
These differences show the great variations in the intensity of whispered
speech. Barth justly distinguishes, therefore, a soft and a hard whisper. To
show the great differences in the results of testing whispered speech in open
and closed spaces, Biot's investigations in Paris demonstrated that one could
carry on conversation in a low whispering voice through a water-pipe 1,040 m.
long (Tyndall).

In order to make a differential diagnosis, it is absolutely
necessary, according to O. Wolf, to use also the qualitative test
for speech, in addition to the quantitative test for hearing. When
performing this test, we must establish the range of hearing—
that is, the hearing distance for the high, middle, and low tones
of speech, and note whether they are heard well, with difficulty, or
not at all, as compared with the normal. On the one hand,
according to the method of Wolf,[*] we allow the patient to repeat
the self-sounding consonants R lingual, B, K, T, F, S, Sh, and
G soft, as well as the very deep whispered U; and, on the other
hand, we select words which have the most prominent sounds.
Words with the self-borrowing letters L, M, N, and W, may be
disregarded while testing. The S-sound, which has the greatest
number of vibrations, will be heard either badly or not at all in
obstructions in the sound-conducting apparatus; the Sh-sound is
heard somewhat better. Failure to hear the F-sound is supposed
to occur in labyrinthine diseases (Wolf). The deepest tone of
speech, according to the above author, is lingual R (with sixteen
double vibrations); in cases in which the membrana tympani is
defective it is often not perceived. The failure of perception for
the lingual R and the whispered U, when the sound-conducting
apparatus is intact, may be considered as an important point in
the diagnosis of a labyrinthine affection when taken in conjunc-
tion with the other symptoms.

When certain words are repeatedly used for testing, they may
easily be guessed by the patient, and errors may thus arise in
judging the improvement in hearing that takes place during
treatment. It is therefore advisable always to use different
words. Testing with sentences is not advisable, as the hearing

[*] Compare Schwabach (*Arch. f. Ohrenh.*, vol. xxxi., p. 82), and E. Bloch,
Ueber einheitliche Bezeichungen der otologishen Functionsprüfungsmethoden,
Z. f. O., vol. xxxiii.

of certain words may lead the patient to guess the entire phrase. Testing with numbers alone is very impracticable, as by their repeated use the whole number is guessed by hearing the vowel.

Only great differences in the hearing distance for speech allow us to come to a conclusion that an improvement has taken place during the course of treatment. As, however, many words are heard at a disproportionately greater distance than others, it is advisable, at the first examination, to fix the distance at which a certain number of words are heard; these should be noted so as to compare the hearing distance for the same words at a subsequent examination. In the case of children, only such words should be used which are within the sphere of their comprehension, as they become tired and restless from long testing.

When testing the acuteness of hearing for speech, special care must be taken that the patient does not watch the examiner, as many patients, especially those who have been deaf since childhood, possess a special skill in reading the lips.

Each ear must be tested separately, the one being turned directly towards the speaker, while the other is hermetically closed with the moistened finger. In unilateral deafness, special care must be taken that the normal ear is closed as tightly as possible; should this precaution be neglected, words spoken in a moderately loud tone in the neighbourhood of the diseased ear may easily be heard by the normal one, and also through the cranial bones or through the Eustachian tube. If this is not borne in mind, mistakes may easily arise; in such cases, therefore, we must avoid speaking too loud in the neighbourhood of the patient. If we wish to be positive whether the patient really heard with the diseased ear, we can test the hearing with both meatuses closed. Should the patient hear at the same distance after closure of the diseased ear, it may be assumed with certainty that he heard with the normal ear; but should he not be able to hear at all, there can be no doubt that speech was heard by the diseased ear before closure.

To determine, in cases of severe deafness, whether speech is heard by means of the membrana tympani and ossicles, or through the cranial bones and Eustachian tube, a long hearing trumpet should be used, the funnel of which is held beyond the range of the patient's hearing distance. If speech is not heard through the trumpet, we can then exclude sound conduction by means of the ossicles. To ascertain whether speech is heard through the Eustachian tube, the mouth and nostrils should be firmly closed and the hearing distance tested. We may conclude with certainty that the patient hears by means of the tube if words which are clearly heard at a certain distance are no longer perceived after closure of the mouth and nostrils.

In addition to the separate examination of each ear, it is advisable to find out at what distance the patient understands speech with both ears, because this does not correspond in most

cases with the results obtained in the separate examination, and, because this is the hearing distance used by the patient in ordinary intercourse. In carrying out the test, the patient faces the physician and looks at the floor. The author regards this method of ascertaining the hearing distance for speech, before and after treatment, the more important, as it affords us a most reliable means by which we are able to judge the amount of improvement. The combined hearing distance thus obtained with both ears open is greater than that of the better hearing ear when tested alone.

Before concluding this chapter, we must still mention a few facts in reference to the disturbance of hearing for speech. Most patients who have a slight degree of deafness understand speech which is not too loud, but clearly accentuated, better than words uttered too loud and quickly. Female voices with a clear, high timbre are better understood than the flat, low voices of males. Habit plays a very important part, and the speech of relatives or acquaintances is much more easily understood than that of strangers. Words which are used in daily life are heard at a greater distance than unfamiliar ones, and a foreign idiom is heard with much more difficulty than one's native tongue. In cases in which the disturbance of hearing is slight, the deafness for certain special words is sometimes remarkable. With a slight degree of deafness, it is exceptional that speech is heard better at some distance than close at hand. In some very rare cases, whispering is heard at a greater distance than loud speech. Musical tones are better perceived than speech. It is for this reason that people with even a high degree of deafness can fully enjoy a concert, while they are totally unable to understand the drama.

B. Testing the Perception for the Waves of Sound conducted to the Ear through the Cranial Bones.

1. Testing with the Watch and Acoumeter.

The vibrations of a body brought into contact with the cranial bones are distributed to all parts of the head, and thus reach the internal ear. These vibrations reach the labyrinth in two ways: (1) by direct conduction through the solid bones to the labyrinth, and (2) by transmission from the cranial bones to the membrana tympani and ossicles, and from these to the labyrinth (*cranio-tympanic conduction*). Henson and Bezold doubt that the waves of sound are perceived by direct conduction through the cranial bones to the labyrinth, but assert that it takes place only through cranio-tympanic conduction. This view is contradicted by the fact that a still stronger perception through the cranial bones is observed when there is a complete loss of the drum membrane and ossicles.

According to Frey,* the sound is conducted through the bones of the head in the same manner as this occurs in all other osseous tissues—that is,

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* Frey, *Experimentelle Studien über die Schallleitung im Schädel. Zeit. f. Psychol. u Physiol. d. Sinnesorgane*, vols. xxviii. and xxxiii.

principally by the most compact parts of the same; in other words, along those parts which are most elastic, and therefore respond most easily to vibrations.   The structure of the petrous portion of the temporal bone appears to him to be especially suitable for this purpose.

The perception for the waves of sound conducted through the cranial bones is greatly modified by pathological changes in the organ of hearing. Attempts have been made to utilize these changes for diagnostic purposes. Although bone conduction for the watch is not considered so valuable for a differential diagnosis, nevertheless it must not be omitted, because in some cases important diagnostic and prognostic indications are thereby obtained

The watch, acoumeter, and tuning-fork are used for testing the perception for sound through the cranial bones. Testing with a weaker instrument, as the watch, cannot be dispensed with in those cases in which it is required to ascertain whether the perception of the acoustic nerve is normal or diminished. If a low-ticking watch is heard, it may be inferred that the perceptive power of the auditory nerve is intact. If the watch is not perceived at all, while the acoumeter is still distinctly heard, we may assume that there is a decrease in the power of perception of the auditory nerve, so that one thereby sees the importance that cranio-tympanic conduction has in middle-ear diseases. If the strokes of the acoumeter are also no longer audible, it may be inferred that there is a severe affection of the sound-perceiving apparatus.

In order to test bone conduction with the watch, it is pressed against the temples, mastoid process, or teeth, while both auditory orifices are tightly closed. The watch is heard the loudest at the last-mentioned place, less loud at the forehead, parietal bone, and occiput. Testing with the acoumeter is carried out in a similar manner, the metal plate of which is brought into contact with the above-mentioned parts of the head. In the majority of cases, the ticking of the watch will be heard in the ear which we are examining, but occasionally, however, it is perceived in the opposite ear.

The power of perception through the cranial bones is more or less diminished in old age owing to senile degeneration of the auditory nerve. Cases are not rare in which a low-ticking watch is not heard through the cranial bones after the fiftieth year; it is rarely heard after the sixtieth year. Therefore, in patients over fifty years of age, the absence of sound perception through the cranial bones has not the same significance as in younger individuals.

In reference to the diagnostic and prognostic value of this method of testing, we may conclude that only in those cases in which we have demonstrated the existence of a middle-ear affection is there a simultaneous diminution in the power of perception of the auditory nerve when there is a complete failure for the perception of the watch or the acoumeter through the cranial

bones. This method, according to the author's opinion, has a positive diagnostic value only in such cases in which the ticking of the watch is still well perceived through the cranial bones, although there is a marked diminution in perception for the watch, acoumeter, and speech through air conduction. Therefore, we may conclude with probability that the disturbance of hearing is due to an obstruction in the sound-conducting apparatus, and not to a labyrinthine affection, providing we take into consideration the results of the tuning-fork tests. This method of testing is, furthermore, of practical value in that the prognosis, *ceteris paribus*, is more favourable in those cases in which the perception for the watch through the cranial bones is present than where it is diminished or entirely absent. In a like manner, the return of the lost perception through the cranial bones must be regarded as a favourable prognostic sign; this may occur in some forms of acute middle-ear inflammations, and in concussions and syphilis of the labyrinth.

The author first called attention to the fact that the watch is heard well on some days through the cranial bones, while on others the perception is entirely absent (intermittent perception). This is observed in acute and chronic middle-ear, but more rarely in labyrinthine affections. Such a phenomenon is produced partly by the various anatomical changes in the middle and internal ear, and partly by the altered tension in the tympanic cavity, having a secondary influence upon the intra-auricular pressure in the labyrinth.

2. TESTING WITH THE TUNING-FORK (SCHWABACH'S METHOD)

1. Testing the Duration of Perception through the Cranial Bones.—Schwabach* was the first to find, in obstructions in the sound-conducting apparatus due to diseases of the external or middle ear, that a vibrating tuning-fork, brought into contact with the cranial bones, is heard longer than under normal conditions,† but that, on the other hand, the perception is shortened in diseases of the auditory nerve. We thus possess a method, even if not always perfect, by which, in pathological cases, we are able to test the power of perception of the sound-perceiving apparatus.

The author uses the c¹ (256 V.) tuning-fork to test the perception through the cranial bones; others employ c (128 V.), or a fork with a 100 V. (Bonnier); Bezold, the forks A and a¹, on the prongs of which there are no clamps. To test the perception for the higher tones, we use tuning-forks from c⁴ to c⁷. The low-toned tuning-forks are unsuitable for this examination, as the great excursions of the prongs are transmitted as a concussion to the cranial bones, and may be mistaken by the patient for a sensation of sound. For this

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* *Z. f. O.*, vol. xiv.; *A. f. O.*, vol. xxxi.

† According to Bing, the time of perception for the tone of the tuning-fork (c¹) is lengthened in the normal ear if the external meatus is closed with the finger.

reason, one should always use a well-made c¹ tuning-fork, which is not only free from overtones, but which does not communicate any concussion to the cranial bones.

The duration of perception through the cranial bones is tested in order to ascertain whether, in a special case, it is shortened or lengthened. In the latter case, the examiner places the vibrating tuning-fork against his own mastoid process, and at the moment when he fails to hear it places it against the mastoid process of the patient. If the patient perceives the tone of the tuning-fork through the cranial bones longer than the normal ear of the examiner, one waits until the patient indicates the moment at which the perception is lost, and one then observes the number of seconds which have elapsed between the perception of the normal and that of the diseased ear (lengthened bone conduction). If we wish to find out whether the duration of perception is shortened, the vibrating tuning-fork is first placed against the mastoid process of the patient, and at the moment when he fails to perceive its tone it is brought into contact with the mastoid process of the examiner, and the difference in time of perception is noted as above (shortened bone conduction). In unilateral affections, or in bilateral disease where one ear is more affected than the other, this method is unreliable, as the perception in the better or normal ear will lead to improper answers by the patient.*

Even in normal-hearing individuals, the time of perception of the vibrating tuning-fork placed on the head is also greatly shortened through traumatic and pathological changes in the vertex of the skull (Wanner and Gudden).†

Although, according to the author's observations, this method can be relied upon alone only in special cases for a differential diagnosis between middle-ear and labyrinthine affections, it nevertheless gives important data from a diagnostic as well as from a prognostic standpoint. It is of value in those middle-ear diseases, complicated with labyrinthine affections, in which the duration of perception through the cranial bones is greatly shortened. It is of diagnostic value, inasmuch as we may conclude that there is an obstruction in the sound-conducting apparatus when the duration of perception is lengthened (negative, Rinne); when, on the other hand, there is a shortened perception (positive, Rinne), with great deafness for speech, we may conclude with great certainty that there is an affection of the auditory nerve. In the latter case, a diseased condition of the auditory nerve may be assumed with greater certainty if there is a very

* According to Siebenmann, the time of perception through the cranial bones varies within certain limits even in persons of the same age and with normal hearing. Dennert thinks that it depends on the age, structure of the cranial bones, and size of the cavities in the mastoid.

† Centralb. f. O., vol. xxii.

great difference in time between the loss of perception at the mastoid process of the diseased as compared to the normal ear.

Schwabach's method is also of prognostic value, inasmuch as the course and result of treatment is more favourable in those cases in which the time of perception through the cranial bones increases rather than diminishes.

2. **Weber's Test (Testing the Perception for the Tone of the Tuning-fork from the Median Line of the Skull).—** Wheatsone, as well as E. H. Weber,[*] found that a vibrating tuning-fork placed upon the skull is heard much more distinctly in that ear in which the external meatus is closed with the finger. The increased sound perception is produced (1) by the increased resonance of the external auditory canal; (2) by the reflexion of the waves of sound transferred through the cranial bones to the air in the external auditory canal, and thence to the membrana tympani and ossicles; (3) by the altered tension of the membrana tympani and ossicles (Politzer).[†]

Weber's test, when combined with other methods of testing, has proved a valuable diagnostic aid in diseases of the ear. Clinical observations show that, in the majority of cases of unilateral affection in which the sound conduction to the labyrinth is hindered by pathological changes in the external meatus or middle ear, a vibrating tuning-fork placed on the middle line of the skull will be heard mainly and stronger in that ear which is the seat of the pathological change, provided that the labyrinth is not simultaneously affected to such a degree that the vibrations of the tuning-fork can no longer be perceived by the auditory nerve.

The same is often observed in bilateral middle-ear affections in which one ear is affected more than the other; still, we often meet with exceptions, inasmuch as the tone of the tuning-fork is heard better by the less affected ear. Weber's method is therefore of little value in chronic bilateral middle-ear affections. On the other hand, in diseases of the sound-perceiving apparatus, provided that they are not complicated with an affection of the external and middle ear, the vibrating tuning-fork, when applied to the median line of the skull, will be heard louder in the normal ear.[‡]

A c (128 V.) or e¹ (256 V), or, according to Bezold,[§] an a¹ tuning-fork, free from overtones, is most suitable for the performance of Weber's test.

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[*] Cp. Politzer, *Ges. der Ohr.*, vol. i., p. 414.

[†] Compare the author's paper, *Ueber Schalleitung durch die Kopfknochen* (*A. f. O.*, vol. i., p. 318).

[‡] The increased perception for the tone of the tuning-fork through the cranial bones in the diseased ear in unilateral affection was already known to the older specialists, but was considered as a symptom of obstruction in the external meatus, tympanic cavity and labyrinth (E. Schmalz, *Erfahrungen über die Krankheiten des Gehörs*, Leipizg, 1846).

[§] *Lehrbuch*, 1906, p. 79.

Low tuning-forks may also be used where the results are unsatisfactory (Brühl). On the other hand, high-pitched forks should never be employed in this test, as they often give an exactly opposite result to that obtained by the c^1 and lower tuning-forks.

This test is carried out in such a manner that one places the vibrating tuning-fork against the median line of the patient's skull. When the test from the vertex gives no positive result, it is recommended to apply the handle of the fork either to the median line of the upper lip against the incisor teeth, or to the median line of the inferior maxilla, from which the sound will more often be correctly localized (Edwin *v.* Millingen).

According to Bonnier and Ostino, the tone of the vibrating tuning-fork placed on the knee in unilateral middle-ear affections is often also lateralized towards the diseased ear.

When the results are doubtful, the sound becomes more distinct in the one ear if the end of an otoscope is inserted into each ear. In unilateral affections, the statements of the patient are very decisive in informing us as to which side the sound is most strongly perceived; the answers of the patient are less reliable in bilateral affections. In such cases, one very often finds, especially in bilateral, chronic middle-ear affections, that the tone of the tuning-fork is heard uniformly in both ears. Sometimes however, it is perceived more distinctly in the one ear from the vertex, while it is heard better in the other ear from the maxillæ or base of the nose.* Even under normal conditions, the vibrating tuning-fork, placed on the parietal eminence, is heard in the opposite ear. According to Frey,† this phenomenon is due to the fact that the vibrations of the tuning-fork, which are transmitted through the skull, are most forcibly carried to the point lying diametrically opposite.

Accordingly, Weber's test is of diagnostic value only in those cases in which the positive statement of the patient shows that the perception for the tone of the tuning-fork, from any point on the median line of the skull, is lateralized principally towards the one, or in bilateral affections towards the more affected ear. We may then conclude with great probability that there is an obstruction in the sound-conducting apparatus. On the other hand, the localization of the tone of the tuning-fork in the better or normal ear is only of little value, as this may occur either in middle-ear or labyrinthine affections. In the latter case, it is of diagnostic value only when taken in connection with the cause of the disease and with the results of Rinne's and Schwabach's tests.

Testing with the watch and tuning-fork often gives contrary results, inasmuch as, on that side where the perception for the tone of the tuning-fork

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* If, as the author first showed, the finger is inserted into the meatus of the normal ear in unilateral affections of the sound-conducting apparatus, the increased sound perception for the vibrating tuning-fork will be transposed from the affected to the normal ear, and upon removing the finger it will again return to the affected side. Therefore, the predominance of sound perception in one ear is able to overpower the perception in the other, in spite of an equal conduction of sound to both. Stenger's test depends on this principle.

† Frey, *Weitere Untersuchungen über die Schalleitung im Schädel. Zeitschrift f. Psychol. und Physiol. des Sinnesorgane*, vol. xxxiii., 1903.

from the vertex is heard better, the watch, when applied to the temple of the same side, is either not perceived or much weaker than by the other ear. The reason for this, according to the author's view, depends in great measure on the difference in intensity of the sound of the watch and of the tuning-fork. Support is found for this opinion in that a metronome, the tick of which resembles that of a watch many times increased, placed upon the vertex, will be heard more loudly in the diseased ear.

Alt proposes the following experiment for ascertaining the presence of a disturbance to the sound-conducting apparatus: If one sings or hums with the mouth closed, the tone, as in Weber's test, will be localized in the affected ear if there is an obstruction in the sound conduction. This test often coincides with that of Weber's, but frequently, however, gives no result.

3. Rinne's Test (Combined Testing of Air and Bone Conduction).—If one holds a vibrating tuning-fork against the mastoid process or other portion of the skull until the tone is no longer heard, and then brings its prongs near the auditory orifice, the tone will again be perceived if the hearing is normal. The normal ear, therefore, hears the tone of the fork longer through the air than through the cranial bones. This is called the positive Rinne test (positive Rinne).

In a physiological paper[*] which appeared in 1855, Rinne claimed that this test was one of general diagnostic value. He stated that in those disturbances of hearing in which the tone of the tuning-fork is perceived stronger and longer through the cranial bones than when held in front of the ear, a disturbance in the sound-conducting apparatus exists. This is called the negative Rinne test (negative Rinne). Where, on the other hand, the tone of the tuning-fork is perceived longer before the ear than through the cranial bones (positive Rinne), we may conclude, according to Rinne, that the sound-perceiving apparatus is diseased. Lucae deserves the credit of having introduced into practice this test, which remained unnoticed until that time. Its important diagnostic significance has been demonstrated by the *post-mortem* conditions found by Politzer, Bezold, and others.[†]

Although the diagnostic value of this test is limited, yet it must be admitted that in a series of cases it gives very valuable data, as often, when other objective symptoms are lacking, a differential diagnosis between a middle-ear affection and an auditory nerve disease can be established by the Rinne test. This test must always, however, be considered in conjunction with the rest of the examination—that is, the amount of deafness for speech, the Weber and Schwabach tests, and the perception for high and low tones.

[*] *Prager Vierteljahrschrift*, vol. i., 1855, p. 72.

[†] Brunner, *Z. f. O.*, vol. xiii., p. 263; Bezold, *Erklärungsversuch. z. Verhalten d. Luft und Knochenleitung beim Rinne'schen Versuch*, München, 1885; Roosa, *Archives of Otology*, 1884; Emmerson, *Z. f. O.*, vol. xiii., p. 53; Schwabach, *Z. f. O.*, vol. xiv., p. 64; Politzer, *Bericht d. Vers. süddeutscher und schweitzer Ohrnärzte*, München, 1885; Eitelberg, *Z. f. O.*, vol. xvi.; Rohrer. *Der Rinne'schen Versuch und sein Verhalten zur Hörweite und zur Perception hoher Töne*, Zürich, 1855 (an exhaustive, praiseworthy paper on the subject).

The general results of this test may be summed up as follows:

1. Rinne's test is a more important diagnostic aid in those cases of obstruction in the sound-conducting apparatus, combined with marked deafness, in which the diagnosis cannot be made by other objective symptoms.* This test is negative in the majority of these cases, provided that no severe complication of the auditory nerve is present.

2. When the Rinne is negative, we may conclude with more certainty that there is an obstruction in the sound-conducting apparatus, the greater the difference of time is between the cessation of perception for tone of the tuning-fork before the ear, and the cessation of perception at the mastoid process. The diagnosis is supported by the failure to perceive low tones, and by the relatively better perception for the high ones, and furthermore by a lengthened perception through the cranial bones (Schwabach).† In unilateral deafness, a negative Rinne allows us to conclude with all the more certainty that an obstruction in the sound-conducting apparatus is present, if, at the same time, Weber's test is lateralized towards the diseased side.

3. In middle-ear affections, in which there is a slight or moderate amount of deafness, Rinne's test is only of slight diagnostic value, as it is positive in the majority of these cases in spite of a lengthened bone conduction. This is very often the case in purulent middle-ear affections with perforation of the membrana tympani. Brühl found that in using low tuning-forks Rinne's test can be negative even when there is a slight degree of deafness.

4. In unilateral middle-ear affections with a great amount of deafness, the diagnostic value of Weber's test is superior to that of the Rinne test.

5. In old individuals, in whom the duration of perception through the cranial bones is, as a rule, shortened (Liebermann), Rinne's test often gives an indefinite result.

6. The result of Rinne's test often remains indecisive in those cases of chronic middle-ear disease which are complicated with an advanced affection of the auditory nerve.

7. When in severe deafness the Rinne test is positive, we may then assume that the auditory nerve is diseased only if, at the same time, the general results of examination, the cause, course and symptoms point to such a condition. The diagnosis is supported by the simultaneous marked decrease of perception for the high tones, with a relatively good perception for the low ones, and by a shortened perception through the cranial bones.

In exceptional cases, the Rinne test can be positive with middle-

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* According to Lucae, Rinne's test can be used as a means of diagnosis only when the hearing distance for whispering has decreased to one metre.

† In chronic middle-ear affections with secondary involvement of the labyrinth Rinne's test can be positive owing to a shortened perception through the cranial bones.

ear affections accompanied by a high degree of deafness, and negative with severe forms of labyrinthine affections. This, however, does not depreciate its value in the least if used in combination with the other methods of testing.

The c* or c¹ tuning-fork is suited for Rinne's test, yet one can also use the c² and, according to Bezold, the a¹. High tuning-forks interfere with the examination, as the air conduction cannot be eliminated. Testing with low tuning-forks is to be avoided, as the concussion to the cranial bones may be mistaken for a tone perception.

The test is performed in two ways: (1) A vibrating tuning-fork is held at the ear until the patient says that he no longer perceives its tone; the handle is then immediately placed against the mastoid process, and the patient is instructed to state the moment when the tone ceases to be heard. The difference of time between the cessation of perception at the ear and the cessation of perception at the mastoid process must be measured in seconds, and noted. Such a mode of procedure is generally observed with an obstruction in the sound-conducting apparatus. (2) A vibrating tuning-fork is first placed against the mastoid process, and as soon as it fails to be heard is held at the ear, and the difference in time between the cessation of perception noted as above. This is the method of testing for positive Rinne. The perception of after-tones and the transmission of the tones of the tuning-fork to the opposite ear interfere with Rinne's test. The latter may generally be avoided by holding the handle of the tuning-fork parallel instead of at right angles to the mastoid process.

4. Gellé's Test (Pressions centripètes).

—If the air is condensed in the normal ear by means of Siegle's speculum, or with an air-bag provided with an olive tip, the tone of a vibrating tuning-fork placed on the vertex will be perceived greatly diminished. This decrease is due to an increased labyrinthine pressure, inasmuch as the membrana tympani, chain of ossicles, and plate of the stapes are pressed inwards. There is no question that the increased tension of the sound-conducting apparatus produces a weakening in the sound perception. If, in a given case, there is a hindrance to the sound conduction—for example, an ankylosis of the stapes—the tone of the tuning-fork, according to Gellé, will remain unchanged during the test. On the other hand, if the labyrinth is affected and the stapes movable, the tone of the tuning-fork will be diminished with every condensation of air just as in the normal state. In addition to this, in labyrinthine affections a more or less pronounced dizziness is often produced by the increased pressure during the application of this method. The cessation of the vibration of the tuning-fork and the unreliable statements of the patient are the disturbing elements in Gellé's test.

Gellé's test is of value only in the severer grades of deafness; it is only in such cases that a positive result is obtained, and even in these it is not constant. On the other hand, it is of little value in deafness of a slight degree, since in mild forms of middle-ear disease the tone of the tuning-fork is also diminished through

* VII. Cong. Inter. d'Otolog., Bordeaux, 1904.

condensation of the air in the external meatus, just as in laby-
rinthino affections. Gellé's test often agrees with the results
obtained by the Rinne test (according to Rohrer, in seven-tenths
of the cases). The former method may therefore be dispensed
with in those cases in which a positive diagnosis can be estab-
lished by means of Rinne's test alone, or when it is combined
with other methods. However, it must be mentioned that in
certain cases of severe deafness in which the other tuning-fork
tests give no definite result, Gellé's test occasionally establishes
the diagnosis (Bloch, Brühl). The author would also like to
lay special stress, in addition to the above-mentioned diagnostic
signs, upon the dizziness which ensues even after a slight pres-
sure, as it is through this dizziness that the diagnosis of a
labyrinthine affection is sustained. Dizziness and a diminution
in perception for the tone of the tuning-fork in this test may
also be absent in labyrinthine affections.

A method proposed by Bing to establish a differential diagnosis between
middle-ear and labyrinthine affections consists in holding a vibrating tuning-
fork against the mastoid process until the tone ceases to be heard, where-
upon it will again become audible if the meatus is closed with the finger.
According to Bing, one may conclude that there is an obstruction in the
sound-conducting apparatus if the tone of the tuning-fork is not heard again
after closure of the meatus; if, however, it is again perceived, a labyrinthine
affection may be inferred. A definite result is obtained by this method only
in cases of severe deafness due to an obstruction in the sound-conducting
apparatus. It is generally unreliable in slight forms of middle-ear affections,
and in diseases of the labyrinth.

Several years ago Dr. Bing also proposed a diagnostic aid for the examina-
tion of deaf people, which he designated the 'entotic' use of the hearing-
trumpet. In carrying out this method, we speak into a hearing-trumpet, the
smaller end of which is inserted into the larger, free extremity of a catheter
which has been introduced into the Eustachian tube. In this way the waves
of sound pass directly into the cavum tympani, where they reach the foot-
plate of the stapes and the fenestra rotunda, and are thus communicated to
the fluid of the labyrinth and auditory nerve. Where speech is not under-
stood through a hearing-trumpet introduced into the external meatus, but is
distinctly audible by the entotic method, we may conclude, according to Bing,
that there is a hindrance to the conduction of sound at the malleus or incus,
and that the foot-plate of the stapes is freely movable.

C. To Establish Unilateral Deafness.

Apart from its importance in army recruiting stations and in
forensic practice, it is of special value for the diagnosis of laby-
rinthine suppurations.

For reasons already given, neither Weber's, Rinne's, nor
Schwabach's test alone can be used to establish the presence
of unilateral deafness. Only the combined results of all these
tests taken in conjunction with the test for speech allow us to
arrive at a positive conclusion. To establish deafness for speech,
the author uses a hearing-tube 2 m. (6 feet) long; this allows the
speaker to stand at a sufficient distance so as to prevent the other

(normal) ear, which is carefully and tightly closed, from understanding the words spoken into the tube. During this test, one must avoid speaking too loud, inasmuch as the transmission of loud sounds through the bones at the base of the skull to the normal ear cannot be completely overcome. It must be mentioned that in some cases speech is not understood at all or only as an incomprehensible murmur, while the perception of a number of tuning-fork tones is still preserved.

It may be said with certainty that there is complete unilateral deafness when, with existing deafness for speech, Weber is lateralized towards the normal ear, a loud-ticking watch placed on the temple is not heard, and the time of perception for the tone of a c^1 tuning-fork through the cranial bones is shortened (Schwabach). The results of Rinne's test in such cases need not be considered.

In order to simplify the tests for unilateral deafness, Wanner[*] recommends—according to his experiences at Bezold's clinic—the use of the a^1 tuning-fork, which has no clamps and which can be heard for 90 seconds. If this tuning-fork is not heard through the air when the normal ear is held tightly closed, it may be concluded that the examined ear is totally deaf.

D. Testing for Simulated Hardness of Hearing and Deafness.

To ascertain whether a case is one of simulated disturbance of hearing is of importance in medico-legal practice, and also to army surgeons, who are entrusted with the examination of individuals for military duty.

The method of testing for simulation must always be preceded by an examination of the membrana tympani and Eustachian tube. If striking changes are found, which allow us to conclude that an affection of the middle ear is present, our chief object in such cases should be to ascertain the degree of deafness.

Conditions are rendered more difficult in cases in which objective signs of a middle-ear disease are absent, as we are then compelled to accept the fact that we are dealing either with a circumscribed affection of the labyrinthine windows or with a diseased condition of the auditory nerve, the diagnosis of which is often very difficult.

For the discovery of a simulated disturbance of hearing when the middle ear presents nothing abnormal, a number of methods of examination have been proposed which will be briefly described.

It must, however, be remarked in advance that, although the premisses are very ingenious upon which these methods are based, still only a few of them prove absolutely certain in practice,

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[*] *Verhandl. d. Deutsch. otol. Gesellsch.*, Wien, 1906.

especially if one has to deal with a cunningly-devised plan of deception, as is so frequently the case.

The procedure to be adopted varies according to whether a unilateral or bilateral hardness of hearing or deafness is simulated. In cases in which deafness of one ear is said to exist, it is first necessary to ascertain whether this organ is totally deaf, or whether hearing power is still present to a certain degree. The examination must always be undertaken with the eyes of the individual bandaged (whereby he becomes perplexed), and with the ear not to be examined closed; the hearing distance of the ear which is said to be affected must then be measured with the acoumeter or with a loud-ticking instrument (as a metronome). These tests must be repeated several times, in order to verify the results obtained. If it is found on repeated measurement that the hearing distance differs only a little, simulation may be excluded, as a normal hearing organ is not capable of judging the distance of a source of sound from the ear within certain limits. Great differences in distance, which are observed at a single sitting, would therefore arouse the suspicion of malingering. This method, which Brigade-Surgeon Dr. Chimani has used for a number of years at the author's suggestion, is preferable to a similar examination with speech on account of the constancy of the source of sound; still, the latter must always be included in performing the test. Great importance must be attached to repeated tests on different days, and to the short duration of such tests, the results of which must be accurately noted each time.

Erhard's test (*Deutsch. militär-ärztl. Zeitschr.*, 1872) is based upon the fact that a normal-hearing ear, even if closed very tightly, is still able to perceive a loud-ticking watch at a distance of 2–3 m.

The individual simulating an aural affection is placed in the middle of a large room, the ear which is said to be deaf is held closed, and the ticking watch is brought within 6–8 feet of the normal ear, whereupon the patient is ordered to count the beats. The normal ear is then held tightly closed, and the supposed diseased ear is examined. If the beat of the watch is not perceived, according to the statement of the patient, at a distance 1–1½ m.— this being the distance at which the tone must also be heard in the closed normal ear—simulation may justly be suspected. According to Tschudi, we may also test with loud speech instead of the watch in this experiment.

Chimani (*Wiener med. W.*, 1869, No. 33) and Moos suggested the following method in testing for a unilateral feigned hardness of hearing: A vibrating tuning-fork of large size (c^1) is alternately held at an equal distance from each ear, whereby it becomes self-evident that the tone is heard better in the ear which is said to be sound. The vibrating fork is then placed on the median line of the vertex or against the incisor teeth, and the patient is then asked in which ear the tone is better perceived.

The individual with a true aural affection (some condition obstructing the sound-conducting apparatus) will, according to Chimani, declare without hesitation that he hears the tone of the fork solely or much louder in the diseased ear, while the person simulating generally hesitates for a moment, as he really cannot distinguish any difference of perception in the one or the other ear, and thinks that he is answering correctly by saying that he hears the tone only in the normal ear, and not at all in the diseased one. If the external meatus of the normal ear is then closed by inserting the finger, and the vibrating-fork is again placed on the vertex, the individual who is really deaf will say that he now hears the tone better in the closed normal ear, or he may no longer be able to distinguish on which side he really perceives it better. The malingerer will state immediately upon closure of the normal ear that he does not hear anything any longer, or only faintly in the diseased ear which has been left open.

The method proposed by Lucae (*A. f. O.*, vol. xlvii.) for determining unilateral simulated deafness consists in screw~ ~~ ~~ andle of a small

A tuning-fork provided with weights to the single branch of a short metal T-shaped tube; a rubber tube 3 cm. long is attached to one of the short branches of this tube, and is intended for the ear which is to be examined. Another rubber tube 56 cm. long is connected with the other short branch of the tube, and is introduced into the normal ear. When the deafness is unilateral the tone of the vibrating fork is heard stronger in the normal ear, and upon removing the tube from this ear this increased perception naturally disappears. A contrary statement by the patient arouses the suspicion of deception. The value of this method can be determined only by its practical application.

Stenger's test is based on the observation first made by the author, that the perception of a tone in one ear can preponderate and completely mask the perception of the tone in the other ear (*vide* p. 155). Stenger uses two c^1 tuning-forks, the tones of which are exactly alike, and notes the distance (with the eyes of the patient closed) at which the one is heard by the normal-hearing ear. The second tuning-fork is now brought nearer to the supposed deaf ear than on the normal side. In a case of true unilateral deafness, the hearing distance for the tuning-fork on the normal side remains unchanged. If, however, there is unilateral simulated deafness, the normal ear perceives the tone only when the tuning-fork is brought nearer the ear than the fork on the apparent deaf side.

Tschudi* proposed another test, which is carried out as follows: Four aural specula of uniform size and form are covered with a small piece of tubing, in order that they may be more securely introduced into the external meatus, and two of them are half filled with wax. The person to be examined is then placed facing a wall with his eyes bandaged, and the two specula without the wax are introduced into his ears, whereupon the hearing distance is ascertained from behind irrespective of the power of hearing of each ear separately. The person is then requested to repeat during this examination, as well as in those which are to follow, every word which he hears. The hearing distance thus found serves mainly as a guide for subsequent examinations, which are undertaken with the closed specula, and then with the open and closed ones, changing them from one ear to the other. This procedure makes it impossible for the person examined to distinguish with which ear he hears—that is to say, to tell whether the good ear is excluded or not, as he always has specula in both meatuses, which give him the sensation of occlusion, and also render it more difficult for him to tell from which direction speech comes to him from behind. It is scarcely necessary to say that absolute quiet must be maintained in the neighbourhood of the patient, and that both specula must always be simultaneously removed and introduced, so that the individual examined obtains no outside clue to guide him. It is thus soon possible to ascertain the hearing distance of the ear which is said to be severely affected or entirely deaf by the fact that, with closure of the normal one, answers are made to speech coming from the other side of the median line, the power of perception of which had been lost when both ears were occluded. The possibility of judging the direction of sound by autophony produced in the occluded ear by repeating the words spoken by the examiner can be excluded, according to the later oral statements of Tschudi, by compelling the person examined, who is placed under the observation of an assistant, to write the words heard by him instead of uttering them.

The detection of deception is more difficult in cases in which the individuals feign bilateral total deafness.† As physical tests of hearing are of no value in these cases, various other devices have been resorted to in order to discover malingering. In the author's opinion, the most reliable test appears to be in waking the patient from his sleep by a moderately loud call. As, however, motor reflexes may also be elicited in total deafness by the concussion of loud

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* *Vide supra*, No. 13, 1891.
† G. Ostino, Congresso otolog. italian., Rome, 1899.

sounds, care must be taken not to approach the person too near, nor to call him too loudly. In some cases, as Burckhardt-Merian reports, the expression of the malingerer's face when offensive remarks are made behind his back by a third person leads to the detection of the imposture. The trick of telling the individual, after the examination, that he is unfit for duty, and may therefore depart, is rather old, and therefore hardly effectual. In the great majority of cases this, as well as a great number of other methods, does not secure the desired result, as one very often meets with shrewd imposters, who, with great obstinacy, carry out their plan of deception, which has been cunningly devised.

Experience and the practised eye of the examiner, which have been acquired from many years' training, must not be under-valued as a means of enabling one to set together a chain of proofs from circumstances which seem of little importance, and which finally make it possible to discover the deception. The striking contradictions which are made by a number of malingerers at repeated examinations, the fantastic statements as to the cause and course of the affection, are often sufficient to arouse suspicion. It not infrequently happens that the suspicion of simulation or exaggeration is already suggested by the altered, anxious, or rest-less behaviour of the patient, as persons who are really hard of hearing or deaf allow themselves to be examined with indifference (Tschudi). Brigade-Surgeon Chimani attached great importance to the general appearance of the individual, to his mental develop-ment, temperament, and the peculiarities of his facial expression and speech, which, if taken in connection with the results of the hearing tests, lead, in the majority of cases, to the detection of the deception.

Testing the Function of the Vestibular Apparatus.

When testing the function of the vestibular apparatus, we must direct our attention (1) to disturbances in equilibrium, (2) to the phenomenon known as nystagmus.

1. Disturbances of Equilibrium.

In testing the vestibular apparatus for disturbances in equilibrium, we must take into consideration that these disturbances, originating in the ves-tibular portion of the labyrinth, are divided into two forms—namely, a static and a dynamic. The static muscular sense depends mainly on the condition of the utricle and saccule, while the dynamic muscular sense is chiefly dependent on the state of the semicircular canals.

In order to test the patient for static disturbances of equilibrium he is made to perform various exercises in that he is asked to stand on both legs with feet together, having his eyes open and closed (Romberg symptom), to stand on the toes with feet together, then on one foot, etc. In addition to these tests von Stein devised an apparatus known as the goniometer, which is provided with a board upon which the individual stands or lies, and arranged in such a manner that it can be raised or lowered. A sextant device, marked off in degrees, allows one to read at a glance the amount of elevation.

Although the goniometer devised by von Stein is of practical value, it is rather cumbersome, so that it is no longer universally em⸮⸮⸮ , our

sounds, care must be taken not to approach the person too near, nor to call him too loudly. In some cases, as Burckhardt-Merian reports, the expression of the malingerer's face when offensive remarks are made behind his back by a third person leads to the detection of the imposture. The trick of telling the individual, after the examination, that he is unfit for duty, and may therefore depart, is rather old, and therefore hardly effectual. In the great majority of cases this, as well as a great number of other methods, does not secure the desired result, as one very often meets with shrewd imposters, who, with great obstinacy, carry out their plan of deception, which has been cunningly devised.

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Testing the Function of the Vestibular Apparatus.

When testing the function of the vestibular apparatus, we must direct our attention (1) to disturbances in equilibrium, (2) to the phenomenon known as nystagmus.

1. Disturbances of Equilibrium.

In testing the vestibular apparatus for disturbances in equilibrium, we must take into consideration that these disturbances, originating in the vestibular portion of the labyrinth, are divided into two forms—namely, a static and a dynamic. The static muscular sense depends mainly on the condition of the utricle and saccule, while the dynamic muscular sense is chiefly dependent on the state of the semicircular canals.

In order to test the patient for static disturbances of equilibrium he is made to perform various exercises in that he is asked to stand on both legs with feet together, having his eyes open and closed (Romberg symptom), to stand on the toes with feet together, then on one foot, etc. In addition to these tests von Stein devised an apparatus known as the goniometer, which is provided with a board upon which the individual stands or lies, and arranged in such a manner that it can be raised or lowered. A sextant device, marked off in degrees, allows one to read at a glance the amount of elevation.

Although the goniometer devised by von Stein is of practical value, it is rather cumbersome, so that it is no longer universally employed. In our

routine examination we confine ourselves to the tests given here, and find that they suffice in apprising us of any disturbance in equilibrium which may be regarded of otitic origin.

To test the dynamic disturbances of equilibrium we make the patient (1) walk forwards with rigid legs; (2) jump on two feet close together; (3) rotate with the feet together; (4) rotate on one foot. These tests are carried out with the eyes closed.

2. Nystagmus.

As we have seen in a previous chapter, the function of the vestibular apparatus is to inform us of the motions of the head, and consequently of the body in space—that is, in apprising us of the relative position of our body to the line of gravity, and thus allowing us to sustain our equilibrium. Any pathological changes taking place in the vestibular portion of the labyrinth become evident as disturbances in equilibrium, which are often associated with other phenomena, such as nausea, vomiting, and nystagmus. In testing for any disturbance in equilibrium, we must remember that the co-ordinated movements of the body are governed by the semicircular canals, so that any pathological changes taking place in these canals become evident as a dis-organized co-ordination of our muscular sense—that is, we are no longer able to appreciate a proper orientation of our body in space. We will not dwell here upon the anatomy and physiology of the internal ear, as these have been fully detailed in previous chapters (pp. 64, 86). Our main interests centre themselves, however, in the various phenomena encountered in the normal and pathologic-ally diseased labyrinthine portion of the aural mechanism. It is chiefly through the investigations and writings of different authors, beginning far back with Flourens, who noticed striking motor disturbances after section and destruction of the semi-circular canals, in addition to others such as Purkinje, Högyes,[*] Ewald,[†] and in recent years particularly Barany,[‡] that our interests have been awakened to the important rôle played by the internal ear, and especially by the three semicircular canals. These authors have shown conclusively that pathological changes taking place there are associated with disturbances of equilibrium, with or without nausea and vomiting, and reflex oscillatory movements of the eyes which we designate nystagmus. It is this latter phenomenon of vestibular irritation which has during the last decade aroused special interest, and has proved

* Högyes, *Neuere Untersuchungs-Methoden zum Studium der Function des Nerv. vestibularis.* Orvosi Hetrlap, 1902.

† Ewald, J. R., *Physiologische Unterschungen über das Endergan. des Nerv. octav.* Wiesbaden, 1892.

‡ Barany, Robert, *Ueber den vom Vestibularapparat des Ohres ausgelösten Nystagmus,* etc. (*Monatsch. für Ohrenheilk,* vol. xl., 1906). *Ueber den vom Ohre auslösbaren Nystag.* (*Zeit. f. Ohrenh.,* vol. li.). *Beitrage zur Lehre von der Funktion der Bogengänge* (*Zeit. f. Sinnesphys.,* vol. xli., 1906). *Physiologie und Pathologie des Bogengangs-Apparates beim Menschen.* Deuticke, 1907.

of vast importance in aiding us to determine the state of the inner ear and its relation to intracranial conditions. That reflex phenomena such as vertigo, nausea, and vomiting are produced when irrigating the ears has been a recognized fact since many years. It was as far back as 1868 that Schmedekam was the first to call attention to these reflex phenomena, so that, since that time, the subject has been more closely analyzed and brought to a clearer understanding by the investigations of such men as Hitzig, Breuer,* Ewald, Baginsky, and many others, and in particular in recent years by the thorough studies of Barany. By nystagmus we understand a reflex stimulation of the ocular muscles which is apparent as vibratory movements of one or both eyes, and which may be of an oscillating or of a rhythmical character. Nystagmus may furthermore be regarded as an oscillating movement of the eyes dependent on the disturbance of a central co-ordinating apparatus, and representing an effort on the part of such an apparatus to restore the function of equilibrium as it relates to the ocular muscles. The former—that is, the oscillating form—is generally observed with ocular defects originating in the eyes themselves, while the latter, which interests us here mainly, has its origin in the vestibular portion of the labyrinth.

Vestibular nystagmus is observed in two distinct forms. In the one, the motions of the eyes are of a pure undulating character —that is, with each excursion of the eye the movement takes place from side to side or laterally with an equal amount of excursion and with the same rapidity. In other words, both movements of the nystagmus are of equal rapidity and of equal length. In the other, the motions of the eyes are not oscillatory, but take place jerkingly in rhythmical succession with a fixed rest period between. In other words, the nystagmus consists of a slow and rapid movement or component, both being of equal length. In defining nystagmus we recognize a *vertical, horizontal, diagonal,* and a *rotatory,* based on the direction of the rapid component, as, for example, a horizontal nystagmus with rapid component to the left, etc. Nystagmus may be due to various causes, and is observed in different forms. We find accordingly a voluntary nystagmus, a physiological rhythmical nystagmus, miner's nystagmus, a congenital nystagmus (optic), as is seen in albinos, a nystagmus due to diseases of the central nervous system, etc., but in this chapter we are mainly concerned with nystagmus of vestibular origin.

In order to elicit nystagmus we resort to various means. (1) Thermic agencies, in that we stimulate the labyrinth by

* Breuer, J., *Ueber die Bogengänge des Labyrinths* (*Allegemeine Weiner med. Zeitung,* 1873). *Ueber die Funktion der Bogengänge des Ohrlabyrinth* (*Weiner med. Jahrbücher,* 1874). *Neuer Versuche an den Ohrbogengängen* (*Pflüger's Arch.,* No. 44).

irrigating the ears with cold and hot water ranging from 60° to 68° F. below body temperature to 100° to 110° F. (2) Rotation of the entire body, in that the patient is placed in a revolving chair, either in an upright or reclining position, and rotated ten or twelve times either to the right or left. (3) Galvanic current, by placing an electrode over each mastoid or tragus region, and allowing the current to pass directly through the head by way of the petrous portion of the temporal bones; or by placing the one pole (either anode or cathode) against the ear, while the other pole is placed against some other part of the body. This is particularly advantageous when testing each labyrinth separately. (4) Condensation and rarefaction of air in the external canal, causing a change of pressure in the labyrinth.

It is now definitely understood that we recognize three forms of nystagmus—namely, a *rotatory* nystagmus, a *caloric* nystagmus, and a *galvanic* nystagmus. When we observe a nystagmus of otitic origin we find that it is always rhythmical, and composed of a slow and rapid component, the difference between the two being usually very pronounced. One does see in rare cases, however, that the difference is very slight, and that the two components are very rapid and limited in excursion. We designate the nystagmus according to the direction of its rapid component.

(a) *Rotatory Nystagmus.*—As a general rule, nystagmus appears at the tenth revolution while turning for a period of three to four minutes around an axis of 360°. To test the right labyrinth, the patient is rotated to the left; to test the left labyrinth, he is rotated to the right. The direction and form of the nystagmus is entirely dependent upon that particular semicircular canal which is stimulated, and the direction in which the endolymph moves. That this is so has been fully demonstrated by the experiments and investigations of Ewald, Högyes, and others, who have also proved that the motion of the fluid can cause movements of the eyes when it flows, either from the smooth end of the ampulla, or from the utricle through the ampulla towards the smooth end. Accordingly, we find that the movements in each eye during rotation takes place through a plane passing through the bulbus oculi, and at right angles to the turning axis of the head, and, furthermore, one notices that the slow component of the nystagmus is in an opposite direction to the rotation. That a nystagmus can be produced in any direction by changing the position of the head during rotation has been clearly demonstrated by the investigations of Breuer and others. It has been found that if one wishes to elicit a vertical nystagmus, one must incline the head of the patient 90° towards the shoulder and rotate the body in a vertical axis. To induce a rotatory nystagmus, the head must be bent 90° forward during rotation in the same axis. If the head is inclined slightly forward we observe a combination, horizontal and rotatory nystagmus, both being in the same direction. By

bending the head backwards 90°, so that the occiput touches the back of the neck and the body is rotated to the right, there is produced a nystagmus to the left; but when rotation ceases, a rotatory nystagmus to the right is observed. When the head is only slightly inclined backwards, we find that rotation to the right produces a combination of a horizontal nystagmus to the right, with a rotatory nystagmus to the left, and on cessation of rotation the reverse takes place.

It must be borne in mind that the direction in which the patient looks is important in determining the nystagmus. If, therefore, the patient is told to look to the left, one will notice a horizontal nystagmus, while, on the other hand a rotatory nystagmus will appear if he looks to the right. We furthermore observe that a horizontal nystagmus to the right is most pronounced when the patient looks to the right—that is, when looking in the direction of its rapid component; it is less marked when looking straight ahead, and greatly diminished or entirely absent when looking to the left.

In a like manner a rotatory nystagmus is increased when looking towards the fast component, and reversely decreased when looking in the opposite direction. From the foregoing it is therefore evident that a change in position of the head during rotation of the entire body causes a change in the flow of the endolymph, which becomes manifest in the various forms of nystagmus.

(b) *Caloric Nystagmus.*—This form of nystagmus is produced by allowing a thermic irritation, such as cold or hot water, to play upon the labyrinthine wall, thereby causing a direct action on the labyrinthine fluid. It will, therefore be noticed that the reaction comes on more rapidly in those cases in which the drum is partially or wholly destroyed.

The various forms of nystagmus observed during irrigation with hot or cold water may be attributed to a partial cooling or heating of the labyrinthine contents, causing a change in the movements of the endolymph. These changes are based on the physiological principle that the specific gravity of the endolymph is raised or lowered according to the temperature of the injected water, and that the labyrinth is a closed vessel filled with a fluid at body temperature. When irrigating the ear with cold water (60° to 68° F.), the promontory wall is cooled off, causing the fluid within to become likewise cooled, so that its specific gravity is increased, causing it to fall to the floor of the vessel. If, on the contrary, hot water is used, the opposite effect is produced on the labyrinthine contents, so that the specific gravity is decreased and the fluid has a tendency to rise. This difference in temperature causes a change in the circulation of the endolymph, which lasts until the temperature of the endolymph equalizes that of the injected water. If the head is placed in different positions, or

rather at various angles during irrigation, the circulation of the endolymph is thereby affected, as another part of the labyrinthine structure assumes its lowest part toward which the endolymph gravitates. Certain motions of the endolymph give rise to corresponding forms of nystagmus, so that we may assume with a degree of certainty that a fixed movement of the endolymph in a certain direction will invariably produce a nystagmus in a correspondingly fixed direction. If, for instance, we irrigate the right ear with cold water (60° to 68° F.) with the head in an erect position, we produce a rotatory nystagmus to the left. If the head is inclined far back (say 180°,) the nystagmus changes to a rotatory nystagmus to the right. On the contrary, however, if hot water is used with the head bent far back, the rotatory nystagmus to the right is changed to a rotatory nystagmus to the left.

Irrigating the right ear with cold water with the head bent towards the left shoulder produces a horizontal nystagmus to the right, whereas a nystagmus to the left is produced when the head is inclined to the right shoulder. With hot water and the head bent towards the left shoulder, a horizontal nystagmus to the left is observed, while a horizontal nystagmus to the right arises when the head is inclined towards the right shoulder. Experiments have furthermore demonstrated that the position of the semicircular canals has an important bearing on the form of the nystagmus. It has been found anatomically that when the head is held erect the ampulla of the anterior vertical semicircular canal, which lies adjacent to the lateral labyrinthine wall, forms the highest point—that is, the centre of the canal forms the highest part of the entire labyrinthine structure. Accordingly, when the ear is irrigated with cold water, the endolymph should move from the smooth end towards the ampullæ in the utricle. Upon rotation, a rotatory nystagmus to the left is produced if the head is inclined towards the left shoulder. As a result of this, if we irrigate the right ear, a movement of the endolymph from the smooth end to the ampulla takes place in both vertical semicircular canals, and a corresponding movement takes place in the anterior and posterior canals. If the head is inclined towards the left shoulder, the centre of the horizontal canal becomes the highest point, and the endolymph moves from the smooth end through the ampullæ to the utricle. It becomes evident from the foregoing that a change in position of these canals in any direction plays an important part in producing the various forms of nystagmus owing to a change of direction in the flow of the labyrinthine fluid. Simultaneously with the nystagmus we frequently find associate symptoms such as vertigo, nausea, vomiting, and the sensation of moving objects. If the nystagmus is pronounced, there arises, especially with closed eyes, disturbances of equilibrium of a varying degree. This disturbance

may be very slight, or so severe that the individual is unable to walk properly or even to remain on his feet. Such disturbances in equilibrium may show fixed reactions, so that one finds that if, for instance, the right ear is irrigated with cold water, with head erect, a rotatory nystagmus to the left is observed, and the patient accordingly shows a tendency to fall towards the same side. If the head is turned 90° to the left, the individual falls forward; but if the head is turned 90° to the right, the patient falls backwards. Furthermore, if the head is inclined towards the left shoulder, the individual has the inclination to stand firm. Most of the above findings have been obtained by irrigating each ear separately with hot or cold water. The best and most rapid reactions are obtained with cold water, and in the great majority of cases we resort to this examination alone. It has also been found that when both ears are irrigated simultaneously with either cold or hot water, contrary impulses are produced in that the injected fluid strikes both labyrinths simultaneously, thereby causing a counteraction, and at the same time neutralizing each other. In the majority of cases a nystagmus is nevertheless produced when looking to the right or left, which is of less intensity and of shorter duration.

(c) *Galvanic Nystagmus.*—In order to produce a galvanic nystagmus, one must allow a galvanic current to pass directly through the bones of the head, and especially through the petrous portion of the temporal bones. To accomplish this most readily, an anode and cathode is placed against each tragus or mastoid process, and the current allowed to pass through the cranial bones. In general, the best results are obtained with a weak galvanic current ranging from 2 to 6 ma. Another way of producing a nystagmus may be accomplished by allowing the patient to hold a large sponge or electrode in the hand, while the physician places the other electrode against the tragus or mastoid process of the side to be examined. If the irritability of the labyrinth is normal, one can, by the above method, elicit a nystagmus. If the anode is placed against the left ear, for instance, the patient must look to the right, as the anode causes a marked rotatory nystagmus to the right, which is intensified by making the patient look to the right. Looking straight ahead or to the left causes the nystagmus to become greatly reduced or arrested entirely. If the cathode is applied to the left ear, the patient should look to the left, as the cathode produces the direct opposite nystagmus to the left. If we allow a cathode closure to follow an anode closure in rapid succession, there will be noticed at the cathode closure a slow rotatory nystagmus towards the anode, and with the anode closure a slow rotatory nystagmus towards the cathode.

In carrying out these various reactions, one usually uses a current ranging from 10 to 15 ma., which is, however, slightly

painful to the patient, but is readily borne in the majority of cases. Barany usually carries out these tests with the patient standing with closed eyes. Just as in the other tests, one finds that the position of the head plays an important part in altering the form and direction of the nystagmus and bringing about a change in equilibrium, as, for example, if the head of the individual is turned 90° to the right, and the cathode placed against the right ear, he will fall forward when sufficient current is administered, and so on.

It is still an undecided question as to the cause of a galvanic nystagmus. Breuer is of the opinion that the galvanic reaction is due to a stimulation of the nerve-endings in the utricle and saccule. Others think that it is the result of an electric irritation acting on the nerves in the ampullæ, on the branches of the nerve as they enter the ampullæ, or on the root of the vestibular nerve itself. Neumann is of the opinion that it is most likely due to the action of the current on the nerve itself, or on the nerve-centre, inasmuch as a nystagmus can still be elicited in spite of the fact that the labyrinth has been destroyed. Either the cathode or anode can produce such a reaction. The cathode, applied to the ear, puts the vestibular nerve in a state of cath-electronus, causing an increase in its conducting power and producing a nystagmus towards the cathode on the same side. On the other hand, when the anode is applied to the ear, the nerve is put in a state of anelectronus, producing a nystagmus away from the anode towards the opposite side.

Another phase of labyrinthine influence upon the co-ordination of our muscular movements is evinced by the so-called pointing and past-pointing tests. Flourens was the first to show that the semicircular canals played a most important rôle in governing the labyrinthine musculature. In order to demonstrate this fact, we place an individual whose labyrinths are found to be in a normal state in a revolving chair in an upright position. The physician, who stands in front of the patient, orders him to rest his hands on his knees, and to raise his arms so as to touch the fingers of the physician's outstretched hand. In the normal state this is generally an easily accomplished act. We next endeavour to elicit a horizontal nystagmus by rotating the individual or irrigating the ear with cold water as previously described, during which period we order the patient to raise his right arm and endeavour to touch the outstretched hand of the physician. In doing so it will invariably be found that his arm will slowly deviate to the left, which action is analogous to the slow component of the nystagmus.

If, for instance, there is a nystagmus to the right, the patient fails to touch the hand of the examiner, and points beyond it to the left.

From the fact that this past-pointing is due to a canal irrita-

tion and head position, it follows that if one irritation remains constant the other is changed, and the pointing reaction changes accordingly. If, therefore, a horizontal nystagmus is produced to the right with head erect, the pointing reaction takes place in a horizontal direction to the left. In a vertical nystagmus, the pointing reaction, with the head in an upright position, takes place downwards, etc.*

The Method of Examining the Patient.

A thorough examination of the patient is indispensable in establishing a correct diagnosis, in determining the prognosis, and for the application of proper treatment. In examining a patient, we take into consideration the history of the case and the objective symptoms.

When taking the history of the case, we must first ascertain the duration of the disease, which is of importance, inasmuch as the shorter the duration, the more favourable, as a rule, the prognosis. It is possible to ascertain the duration of the affection only if it developed acutely with marked symptoms, or during the course of an acute eruptive disease, typhoid, or as the result of a trauma. The majority of patients, however, are not able to inform us, even approximately, as to the commencement of their ailment. This is especially true of those unilateral, insidious affections which run their course without subjective symptoms, and which are discovered only by the accidental closure of the normal ear, whereupon a disturbance of hearing is noticed. The same also applies to those bilateral, insidious affections in which the disturbance of hearing becomes noticeable only when it has reached such a degree that it markedly interferes with daily intercourse; for example, in persons whose position in life or calling does not make a great demand on their organ of hearing, and who therefore hardly notice slight disturbances of hearing. It not infrequently happens that the origin of an impairment of hearing which has been unsuspected, although existent for a long period, becomes apparent only when subjective noises arise. Patients frequently present themselves who never had the least suspicion that there was an aural affection, and who state that their disease is only of short duration, while objective examination shows extensive loss of substance, calcareous deposits, and cicatricial formations on the membrana tympani. Such changes must have existed for a long time without the patient's knowledge.

The etiology of the affection is just as important as the duration

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* Hubby, Lester M., *A Discussion of the Modus Operandi of Galvanic Nystagmus. Annals of Otology, Rhin.*, Sept., 1913; *Laryngoscope*, Feb., 1913. Mackenzie, George W., *Some Remarks on Nystagmus. Annals of Otology*, June, 1923. Mettler, Lee, *Nystagmus. Ill. Med. Journal*, Sept., 1912.

from a prognostic standpoint.   The prognosis in the idiopathic forms of diseases of the ear is quite different from that in affections produced by scarlet fever, measles, syphilis, and other general diseases.

Diseases of the organ of hearing are produced either by deleterious influences acting directly upon the ear through general diseases, or through diseases of other organs.

Of the direct influences, we must mention traumatisms, the intensive action of sound upon the ear, scalds, burns, and frostbite, as well as vegetable parasites (aspergillus) causing inflammation in the external auditory canal.

Acute and chronic naso-pharyngeal affections (hypertrophy of the mucous membrane, adenoids, polypi, empyema of the accessory sinuses, ozæna, etc.) are the main causes in producing a disturbance of function of a varying degree in the middle ear through continuity and contiguity.   In these cases we are dealing with a bacterial infection conveyed from the naso-pharynx into the middle ear.

Atmospheric influences, the effects of which manifest themselves in what are commonly called ' colds,' have a detrimental effect upon the ear.   The term ' cold ' is often used by the laity for an unknown or merely hypothetical cause of the disease. How much of the theory is true that the protective power of the animal organism—for example, the motion of the ciliated epithelium—is weakened through catching cold, and therefore facilitates infection, has yet to be determined.

General diseases are other causal factors in bringing about affections of the ear, or the latter may develop secondarily to diseases of different organs.   To the former class belong scarlet fever, rubeola, variola, diphtheria, typhoid and the exanthematicus, influenza, mumps, syphilis, tuberculosis, scrofula, rickets, Bright's disease, diabetes, leukæmia, acute rheumatism, gout, and furthermore chlorosis, pernicious anæmia, scurvy, and purpura hæmorrhagica; to the latter class, pneumonia, puerperal infections, and a number of affections of the circulation which are caused by emphysema, valvular lesions, aneurisms, struma, attacks of whooping-cough, pregnancy, and disorders of menstruation.   Besides these, disturbances of hearing of varying degree are brought about by intracranial processes, epidemic cerebro-spinal meningitis, acute and chronic hydrocephalus, apoplexy, encephalitis, sclerosis of the brain, tumours of the brain, and furthermore by tabes dorsalis, hysteria, chorea, and epilepsy.   This is due partly to the extension of the diseased process to the ear, and partly to the involvement of the auditory nerve-root.   In conclusion, we must still mention as deleterious influences the excessive use of tobacco and alcohol, also the action of certain drugs, such as quinine, salicylic acid, antipyrin antifebrin, aspirin, and others, which, when administered inter-

nally, give rise to a temporary or permanent disturbance of hearing.

Hereditary predisposition is another very important cause in bringing about an aural affection. It is well known that hardness of hearing is hereditary in many families, the members of which are afflicted, often during the same years of life, with an impairment of hearing running its course with similar symptoms. This predisposition manifests itself either in the immediate descendants or, according to the author's experience, more often in the second generation. We are justified in assuming heredity as the cause of the affection only when the disturbance of hearing has developed in several members of the same family with similar symptoms and without any demonstrable cause (Hammerschlag). Among the hereditary causes, syphilis and tuberculosis play an important rôle.

Although we are frequently in a position to trace the etiology of the affection to one of the above-named causes, nevertheless we must confess that the source of origin is occasionally uncertain. This is the case not only in regard to a number of acute inflammations of the external and middle ear accompanied by free exudation, but especially to those insidious middle-ear affections which develop without striking symptoms and with a gradually progressive impairment of hearing. One must not be surprised at this if one considers that medical science is, in the great majority of cases, still in the dark regarding the pathogeny and etiology of diseases, especially chronic affections.

The calling and occupation of the patient are other important factors which must be considered in the examination, since some occupations have a tendency to produce an affection of the ear. In those forms of acute and chronic middle-ear inflammations which are amenable to treatment, the chances of a complete recovery are much less in persons who are obliged to expose themselves during the course of the disease to the harmful influences connected with their occupation.*

The detrimental effect of occupation upon diseases of the ear is especially noticeable among certain classes—for example, in chauffeurs, masons, tanners, fishermen, sailors, soldiers in the field, etc.; in a word, in persons who are continually exposed to all the vicissitudes of weather, cold, and moisture. In like manner, some affections of the ear are made worse by the noises associated with certain occupations, which continually act upon the organ of hearing. One therefore observes in locksmiths, blacksmiths, boiler-makers, mechanics, iron-turners, file-makers, plate-makers, tinkers, engineers, stokers, as well as in persons working in noisy machine shops, an increasing diminution in the hearing power, and persistent subjective noises, which increase in

* Röpke's monograph is an exhaustive and instructive treatise on this subject: *Die Berufskrankheiten des Ohres*, Wiesbaden, 1902.

intensity through excessive irritation of the auditory nerve.*
Anatomically these disturbances of hearing are due to structural
changes in the labyrinth, which, however, have been demon-
strated only in a few cases; rarely to a combined diseased con-
dition of the middle ear and auditory nerve.

We must also call attention to the disturbances of hearing
observed in artillerymen, riflemen, train hands, and miners,
which are caused by the sudden condensation of air in the
external auditory canal or by intensive noises. In consequence
of this sudden condensation, we observe ruptures of the drum-
membrane, hæmorrhages into the same and into the tympanic
cavity, and paralysis of the peripheral endings of the auditory
nerve (*vide* chapter on Injuries of the Internal Ear).

Excessive variations in the air-pressure, which occur in caisson
workers, divers, and aeronauts, must be classed among the influ-
ences which are injurious to the organ of hearing. As a result
of excessive increase or decrease in the air-pressure, lacerations
of the membrana tympani, as well as extravasations of blood
into the tympanum and labyrinth, have been known to occur.
In such occupations as glass-blowing and the playing of brass
instruments, disturbances of hearing have been observed, which
could be traced to a venous stasis in the ear as a result of forced
expiration.

Lastly, we must call attention to the industrial poisons which
affect the hearing through an intoxication of the entire system;
this is especially the case in chronic poisoning due to lead,
mercury, arsenic, phosphorus, sulphur, coal-gas products, and
aniline chromate (Rudloff).†

That climate, locality, and mode of life may influence the
course of an aural affection is beyond all doubt.

The onset and course of the affection are also important,
as they not infrequently enable us to come to a conclusion as to
the nature of the disease. It is therefore necessary in every
case to ascertain whether the disease has arisen suddenly with
acute inflammatory phenomena, dizziness and disturbances of
equilibrium, or whether it has developed gradually without
marked reaction and with a rapid diminution in the hearing.
Furthermore, we must determine whether it has taken a slow,
insidious course with gradually increasing deafness, and, lastly,
whether the power of hearing has changed to any considerable
extent or not. Stress must be laid on the last-mentioned fact,

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* Investigations which the author undertook in different tradesmen led
him to conclude that, next to the locksmiths, boiler-makers and coopers
were most frequently afflicted with a disturbance of hearing. In coopers,
according to their own statements, the so-called hollow stroke when hooping
the casks is said to have such a deafening effect that most of them, if they
remain at their trade, eventually become deaf.

† See Hygiene of the Ear.

as marked variations in the hearing distance are chiefly observed in the exudative middle-ear catarrhs which have a favourable prognosis, while in otosclerosis, accompanied by progressive deafness, there are only slight variations in the hearing power.

In taking the history, we must also consider the age of the patient as well as the facts quoted above, as this has an important bearing upon the course, result, and treatment of the disease. In regard to infants, it is beyond doubt that inflammations are induced by the following causes: The changes in the middle ear which take place soon after birth; the rapid absorption of the swollen mucous membrane; the entrance of the liquor amnii and meconium into the tympanic cavity during parturition; and the action of external injurious agents upon the hyperæmic mucous membrane of the tympanum. The acute exanthemata and affections of the naso-pharynx, such as adenoids and tonsillar diseases which are prevalent in childhood, are very often followed by affections of the ear. The frequency of ear diseases decreases in middle age, and again presents a noticeable increase in elderly individuals. This is due not only to the fact that the energy of the auditory nerve is diminished in consequence of retrograde changes in the organ of hearing—progressive atrophy of the endings of the auditory nerve—but also to the frequent development of a chronic, insidious inflammation of the middle ear, which leads to thickening of its lining membrane, and to rigidity of the articulations of the ossicles.

A number of subjective and objective symptoms accompanying ear affections must not be undervalued in the examination of the patient.

The subjective noises which develop in the course of most ear affections require our special attention. They belong to the subjective symptoms of the patient, and are experienced as ringing, knocking, hissing, roaring, whistling, seething, etc. According to the author's observations, nearly two-thirds of all aural patients suffer from subjective noises, and the number who seek medical aid for their relief is very considerable. Objective noises (circulatory and muscular noises, mucous râles) are also not infrequently heard, and are described as blowing, snapping and cracking.

When subjective noises are complained of, we should ascertain whether they are unilateral or bilateral, whether they are perceived in the head or in the ear, whether they are endurable or very troublesome, whether they have a high or low character, by what things they are increased, and whether they are occasional or uninterrupted. This last fact is important, in so far as, according to the author's experience, the prognosis is less favourable in cases in which the subjective noises are continuous than in those in which they occur, or only occasionally. One should, furthermore, examine whether the noises

in the ear are increased or decreased by obstruction of the circulation through compression of the carotid or vertebral arteries (Dundas Grant); whether their intensity is affected by rarefying or condensing the air in the external meatus or by closing the meatus with the finger; whether they are altered by reflex action from the cutaneous branches of the trigeminus, as, for example, by pressure on the mastoid process, or by rubbing the skin in the region of the ear; and, finally, whether their intensity is decreased by the tones of high or low tuning-forks, or whether they are increased or diminished in noisy places (*vide* chapter on Neuroses of the Acoustic Apparatus).

Pain generally accompanies diseases of the ear. It is especially intense in furunculosis of the external meatus, in acute myringitis, in acute middle-ear inflammations, and in caries of the temporal bone.

When the patient complains of pain, we must determine whether it is located in the region of the external ear or in the deeper parts; whether it is limited to the ear or extends towards the vertex, occiput, or region of the neck; whether or not it is increased by pressure upon the external region of the ear and mastoid process; whether and how often it occurs during the course of the disease; and whether it is irregular or occurs in regular paroxysms. Besides this, it is most important to determine the cause of the pain in every case by objective examination. If we can exclude an inflammatory process by ocular inspection, it is necessary to ascertain whether we are dealing with a neuralgia, whether this is located in the external meatus or tympanic plexus, and whether it is a local affection or a part of a trigeminal or cervico-occipital neuralgia. Furthermore, in such cases we should never neglect the examination of the teeth, as, especially in children, the pain very often radiates towards the ear from carious teeth. In like manner pain may radiate to the ear from ulcerative processes in the pharynx and larynx (*vide* chapter on Otalgia).

Dizziness is one of the most important symptoms connected with diseases of the ear. It not only occurs in diseases of the labyrinth and in deafness of cerebral origin, but is not infrequently observed in those affections of the middle ear which cause an increased pressure in the labyrinth. Where this symptom exists, one should test its intensity by allowing the patient to stand and to walk with open and closed eyes, and by rotating the body. One should then observe to which side there is a tendency to fall, and whether the dizziness is increased or diminished by forcing air into the middle ear, or by rarefying or condensing the air in the external meatus (*vide* chapter on Symptoms of Ménière's Disease). Further, it must be ascertained whether there is nystagmus, to which side the fast component is

directed, and whether it changes according to the position of the head.

Finally, we must take into consideration a series of abnormal sensations described as pressure fulness, and a feeling of tightness of the ear and head; these are, on account of their annoying character, often placed in the foreground by the patient. To these unpleasant symptoms we must still add the resonance of the patient's own voice (autophony), which frequently occurs in unilateral accretions of cerumen and with a swollen or patulous Eustachian tube; and, furthermore, the painful sensations caused by sound, known as hyperæsthesia acustica, which occurs in nervous individuals, and in slowly progressive ear affections, accompanied by a high degree of deafness.

The first objective symptom to be determined is the presence or absence of a discharge. When it exists we must ascertain when it began, and whether it is copious or scanty; furthermore, whether it is purulent, mucous or bloody, whether or not it is offensive, whether it has been continuous or interrupted, and whether there is a subjective relief when the discharge ceases, or, on the contrary, a feeling of fulness and pain in the ear (*vide* chapter on Acute and Chronic Suppurations of the Middle Ear).

The disturbances of hearing which we will now mention will be more minutely discussed in the following chapters; they are of less importance than those noted above, but under certain circumstances become of great importance. To this class belongs the power of hearing better in noises—for example, in vehicles and in trains (*paracusis Willisii*). This occurs most frequently in adhesive processes of the middle ear which run their course without secretion, especially in otosclerosis, and is generally, therefore, to be considered an unfavourable prognostic symptom. *Paracusis localis*, or the inability to localize the direction of sound, is another symptom belonging to this class, and is usually observed in unilateral deafness of high degree; it is seldom mentioned voluntarily by the patient, but only after questioning by the physician. This phenomenon may be explained by the fact that it is possible to judge the direction of sound only by binaural hearing (*vide* chapter on Neuroses of the Acoustic Apparatus).

An estimation of the facts connected with the history of the case, as well as the most important symptoms in connection with the results of the methods of examination previously described, are sufficient, in the majority of cases, to enable us to form an opinion as to the nature of the affection and its prognosis. The mode of procedure which the physician should follow in the objective examination of his patient will next be given in regular order.

The objective examination of the patient is begun with the

inspection of the auricle, external meatus, and membrana tympani. One should never omit, before inserting the speculum, to examine the region of the external auditory orifice and the external portion of the auditory canal, as certain changes, limited to this area, such as circumscribed eczema and fissures, may be covered by the speculum, and may thus easily be overlooked. After introduction of the speculum, the meatus is examined in reference to its capacity and curvature, its vascularity and character of its secretion; we furthermore ascertain by inspection, and eventually by probing, the nature of existing obstacles caused by normal or pathological accumulations of secretion, fungi, polypoid growths, exostoses, or other diseased processes leading to stricture of the meatus.

If there is no obstacle preventing the inspection of the membrana tympani, its different portions are examined as to colour, lustre, transparency, and curvature; this is accomplished by slightly changing the position of the speculum. We are thus in a position to observe the degree and extent of vascular injection, the size and colour of existing opacities and chalk deposits, and the form, position, and extent of perforations, cicatrices, and atrophied spots; and, further, the presence of a general or partial bulging, which may be caused by infiltration, bullæ, abscess formation, as well as by granulations and polypi. In like manner, we must take into consideration the general or partial retractions of the membrane and their relation to the incudo-stapedial joint and to the inner tympanic wall.

We next direct our attention to the position and inclination of the manubrium, the size and prominence of the processus brevis and of the posterior fold of the membrane, the form and extent of the triangular cone of light, the colour and amount of visible exudate in the tympanic cavity, and, in case of perforation, the condition of the inner tympanic wall. We must not omit examination with Siegle's speculum, in order to ascertain the tension and mobility of the membrana tympani; this applies to those cases in which it is abnormally bulged, as well as to those in which it appears normal.

The use of the probe in the tympanic cavity is one of the most important diagnostic aids; it cannot be dispensed with in those cases in which it is necessary to ascertain the seat of granulations and polypi in the meatus, on the membrana tympani, or in the tympanic cavity. It is, furthermore, of value to diagnose caries or necrosis in the temporal bone, which are beyond ocular inspection (*vide* chapter on Aural Polypi and on the Carious and Necrotic Affections of the Temporal Bone).

Having ascertained the condition of the membrana tympani, we next direct our attention to the hearing function. We first determine the acuteness of hearing for the acoumeter or the

watch, then the perception for low and high tuning-forks through
the air, the hearing distance for speech, and, finally, the power
of perception through the cranial bones for the watch, acoumeter,
and tuning-fork (Weber's and Rinne's test, the duration of
perception through the cranial bones).

We next examine the condition of the Eustachian tube and
tympanic cavity by the Valsalvan experiment, then by Politzer-
ization, and, should these methods prove unsuccessful, by the
catheter. During these procedures we must notice chiefly the
auscultation sounds in the middle ear, and the changes on the
membrana tympani after an inflation of air, especially alterations
in its colour and curvature, in the form of the light reflex, and
in the position of the handle of the malleus.

After the middle ear has been examined, the hearing is again
tested in the above manner, in order to ascertain the difference
in the power of perception before and after inflation. This is
of the greatest importance from a diagnostic as well as from
a prognostic standpoint. As a rule, we may infer that the
prognosis is favourable in those diseased processes (swelling and
secretion in the middle ear, anomalies of tension, etc.) in which
a considerable increase in the hearing distance takes place after
an inflation. On the other hand, in cases in which no improve-
ment in the hearing, or only a slight one, follows the inflation,
the prognosis is more unfavourable, as we may assume with
probability that the disturbance of hearing is due to some
organized, irremovable, diseased product in the middle ear, or
to changes in the labyrinth.

It is also very important to find out the nature of the subjec-
tive noises after the Eustachian tube has made been permeable.
If we are informed that they are markedly diminished, this may
be taken as a favourable prognostic sign, and we have the right
to suppose that they are partially dependent on pathological
changes in the middle ear, which are producing pressure on
the contents of the labyrinth. If, on the other hand, the noises
remain unchanged after inflation, we may conclude, in the
majority of cases, that there are permanent changes in the ear,
which render the prognosis unfavourable.

According to the author's experience, he lays great stress on
questioning the patient whether in troublesome pressure and
fulness in the ear he places his finger tightly in the external
meatus, and by repeatedly shaking it seeks to rid himself of
these disagreeable sensations. Many patients do this habitually,
in order to bring about a temporary improvement in hearing.
It is also important to ascertain, especially in chronic middle-ear
affections, whether the patient has frequently used the Valsalvan
method, because if not asked he seldom informs the physician
of this fact. Each of these manipulations carried out to excess
exercises, as experience shows, the most detrimental effect upon

the hearing. This misuse of the Valsalvan method, as practised habitually by many, may produce a high degree of disturbance of hearing if the physician does not warn the patient in time.

In middle-ear inflammations, especially in acute and chronic suppurations, it is absolutely necessary to examine the region of the mastoid process very thoroughly, because inflammations which have extended to that part produce palpable changes in the external cortical layer, the periosteum, and the integument, the early discovery of which is very important for determining the mode of treatment to be adopted. We therefore gently palpate the region of the mastoid to ascertain whether there is an infiltration of the periosteum and skin, and whether there is fluctuation present; also whether, and to what extent, pain is produced by pressure and percussion upon the bone, what part of the mastoid is most sensitive to pressure, and whether a fistulous opening or cicatrix exists. In inflammatory affections of the mastoid, with swelling of the side of the neck, it must be further ascertained whether there is a tense infiltration of the tissues below the process, or whether there is a sinking abscess of otitic origin. The cervical and lymphatic glands in this region are often swollen and infiltrated in inflammations of the external meatus and middle ear, especially in purulent affections. Therefore, this always necessitates their examination, as a decrease in the infiltration may generally be considered a favourable sign.

We now direct our attention to the examination of the naso-pharynx with reference to congestion, swelling, secretion, adenoid vegetations, ulcerations, and especially to the state of the tubal orifices. We must mention here, however, that a rhinoscopic examination is imperative when the combined symptoms demand it. These symptoms are produced by changes in the invisible portions of the naso-pharynx, increased secretion, palpable obstacles in the naso-pharynx, and difficulty of breathing through the nose. In case of a nasal obstruction, our attention is already drawn to the naso-pharyngeal affection by the peculiar expression of the face, which arises from breathing through the widely-opened mouth, from adenoids, or from any other obstruction to nasal breathing.

Although the result of the objective examination of the ear and its neighbouring parts, together with the history of the case generally, suffice to indicate the therapeutic measures to be employed, it is often necessary, however, to take into consideration the general health of the patient. This is of the greatest importance, as not only does a relation often exist between the aural affection and the general disease, but not infrequently a rational treatment of the latter has a favourable influence upon the former.

After having ascertained the objective symptoms, we must then direct our special attention to the other organs, provided the history of the patient demands a general investigation. The

following conditions make such an examination necessary: Frequent attacks of pulmonary catarrh, hæmoptysis, palpitation of the heart, continuous headaches, attacks of dizziness, anæsthesia and hyperæsthesia, or symptoms of paralysis, neurasthenia, and hysteria; further, the admission of a past or present syphilis and the general appearance of the patient.

The examination of the urine for sugar, albumen, and increase in the amount of urates is of great importance, as the excretions of a diseased kidney greatly modify the course and result of the aural affection. We know that pruritus and frequently recurring furunculosis of the external meatus usually appear as the first symptoms of diabetes; and, furthermore, that acute and chronic middle-ear affections of diabetic origin run an unfavourable course, and that a carious condition of the temporal bone is more easily brought about in patients with this diathesis.

In like manner, the appearance of albumen in the urine, as a result of an acute or chronic nephritis, must be regarded as an important symptom, because during the course of these diseases exudations in the tympanic cavity repeatedly take place, as well as hæmorrhagic inflammations of the middle ear and diseases of the labyrinth, which are accompanied by sudden deafness.

An increased excretion of urates and oxalates also demands the attention of the otologist, as this is not infrequently an accompanying symptom of otosclerosis.

Lastly, the ophthalmoscopic condition of the fundus must be ascertained in all cases in which, in the course of an acute or chronic middle-ear suppuration, symptoms of a cerebral complication, or a sinus phlebitis present themselves. In sinus phlebitis, as well as in cerebral disturbances of hearing, the changes in the retina, such as retinitis, ecchymosis, choked disc, etc., furnish important aids for the diagnosis.

It may be in place to mention a few facts regarding the hygiene of the ear.* In reference to prophylaxis, patients must be warned against the too thorough and too frequent cleansing of the ear with small sponges, with the rolled end of a towel, and with ear-spoons (hairpins). These manipulations cause the greater part of the ceruminal secretion to be pushed into the deeper parts of the ear and favour the formation of ceruminal plugs.

It is furthermore not advisable, when washing the face, to allow the water to flow into the ear, because, apart from the frequent macerations of the epidermis which may take place, the ceruminal secretion of the cartilaginous meatus becomes more fluid and flows into the deeper parts, where it forms plugs. The heads of infants should never be placed under water when they are bathed, as not infrequently an acute otitis is brought

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* An exhaustive treatise on the subject is contained in an excellent work, *Igiene del orechio*, by Professor Cav. V. Cozzolino, which has been translated into many languages.

about by the water entering the meatus or the Eustachian tube during an act of swallowing.

The entrance of water into the ear when washing and bathing has a special detrimental effect in eczema of the ears, in suppurative middle-ear processes, and in middle-ear suppurations which have run their course and in which there is a persistent perforation. In the latter case, a small quantity of water is sufficient to bring about a relapse of the suppurative disease.

On these grounds, aural patients should not be allowed to duck their heads under water while bathing, and they should be specially cautioned in reference to diving; it is also wise to warn those with normal ears against the detrimental effects of the above, inasmuch as the author has repeatedly observed, especially in patients with wide and straight meatuses, the occurrence of dangerous aural diseases after such procedures. When taking sea baths, it is recommended to close the external meatus with cotton, and to protect the ears with a bathing cap.

If there is an itching in the ear, it is a bad habit to scratch the meatus with ear-spoons, hairpins, etc., as they often cause painful partial or diffuse inflammations of the external auditory canal. Such inflammations are brought about by erosions of the cutis covering the meatus and to subsequent bacterial infection. Any itching in the ear which is of an annoying character should be treated by a physician.

Pathogenic micro-organisms not infrequently enter the middle ear through injudicious manipulations and by blowing the nose forcibly during an attack of acute naso-pharyngeal catarrh. Instead of the customary habit, it is therefore recommended to close alternately each nostril and to get rid of the secretion by means of a forcible expiration. Habits which are practised by many, and which are still more harmful, are the snuffing up and syringing of cold water into the nose, or the use of a nasal douche. The solutions used in naso-pharyngeal affections should be employed only under moderate pressure in the form of a spray by means of an atomizer.

The author was convinced from observations in his clinic that in large cities, where the atmosphere is full of bacteria, acute suppurative middle-ear affections occur more often than in the country. These affections occur much oftener and with greater severity in poor people; in the latter class, the growth of pathogenic bacteria is favoured owing to insanitary surroundings. During the process of inspiration the germs reach the naso-pharynx, and from here enter the middle ear.

Aural affections, which are of a dangerous character, can be reduced to a minimum through a simple methodical disinfection of the naso-pharynx. Patients should be taught to keep the nose and naso-pharynx free from infection by using an antiseptic cleansing spray several times a day. Nasal douches and irriga-

tions should be avoided, as the fluid may be forced through the Eustachian tubes into the middle ear, and give rise to marked inflammatory conditions.

The hygienic condition of a man's calling or occupation plays an important part in the hygiene of the ear. Most of the industrial institutions work with raw material, which has a more or less detrimental effect on the organ of hearing. Not only the raw material itself, but the small particles of dust which arise from working the same, as well as the gases and the steam, affect the auditory apparatus. To the first group belong those who work in arsenic mines,* in whom, owing to chronic arsenic poisoning, diseases of the internal ear are brought about. To the second group belong all those who work in industrial institutions, in whom, through insufficient ventilation, there occur diseases of the upper respiratory tract, and as a consequence middle-ear affections. In regard to the above, workers in iron foundries and file-smiths (Röpke) are especially subject to this danger. The sharp metallic dust often causes eczema of the external ear and sometimes perichondritis; the carbonic acid gas produces a labyrinthine affection, accompanied by subjective noises (Rohrer,† Kayser‡). To this group belong, further, those cases of ulceration and perforation of the nasal septum which were first referred to by Rudloff.§ These ulcerations and perforations also occur in those who work with chromic acid in consequence of inhaling the dust or vapour formed by the chromates. Rohrer|| calls attention to the fact that phosphorus necrosis may also extend to the temporal bone in those who work in phosphorus factories.

It has already been referred to (p. 174) that certain occupations which are associated with loud noises are detrimental to the organ of hearing.

Workers in boiler factories, in stamping and rolling mills, and in nail, file and machine factories, as well as coopers, millers, artillerymen and engine-drivers, are often affected with progressive deafness, due to a progressive atrophy of the auditory nerves and their ganglia (Habermann,¶ Wittmaak,** Barr,†† Brühl‡‡). Injuries are also to be considered amongst the harmful agencies of certain trades. For example, in iron foundries one sees ruptures of the membrana tympani which are brought about by small bits of flying iron and by burns with red-hot dross and molten iron (Schwartze,§§ Alt||||). The same applies to stonemasons and workers in stone-quarries.

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* *Lewin*, cited by *Röpke : Die Berufskrankheiten des Ohres und der oberen Luftwege*, Wiesbaden, 1902.

† Haug's *Klin. Vortr.*, vol. i.   ‡ *Wien. med. Woch.*, 1893.
§ Ninth meeting of the Deutsch. otol. Gesellschaft. || *Loc. cit.*
¶ *Arch. f. Ohren.*, vol. xxx.   ** *Zeit. f. Ohren.*, vol. li.
†† Glasgow Phys. Society, 1886.   ‡‡ *Zeit. f. ärztl. Fortbildung*, 1904.
§§ *Lehrbuch*, p. 82. |||| *Archiv f. Ohren.*, vol. xxxii.

In caisson and tunnel workers one occasionally sees a form of aural affection which may be prevented if certain precautions are observed.   In this class of workers an apoplectiform labyrinthine disease comes on in consequence of the great variations in the air-pressure, and is probably caused by the formation of gas emboli in the vessels of the labyrinth (v. Schrötter, Heller, and Mager,[*] Moos,[†] Alt[‡]).   Glass-blowers often suffer from tinnitus (Bürkner[§]), the cause of which, according to Röpke,[||] is a congestion and hyperæmia of the labyrinth.

[*] *Monat. f. Ohren.*, vol. xxxi.   [†] *Zeit. f. Ohren.*, vol. xiii.
[‡] Sixth meeting of the Deutsch. otol. Gesellschaft, Dresden.
[§] *A. f. O.*, vol. xxi.   [||] *Loc. cit.*, p. 56.

DISEASES OF THE SOUND-CONDUCTING APPARATUS.

Special Part.

I.

DISEASES OF THE EXTERNAL EAR.

(Auricle and External Meatus.)

Anomalies of Secretion in the External Auditory Meatus.

Hypersecretion of the Ceruminous Glands. Formation of Ceruminous Plugs.

THE cerumen, a product of the ceruminous and sebaceous glands, is secreted mainly in the cartilaginous meatus, and only to a small extent at the commencement of the osseous portion. Under normal circumstances, it is removed partly by the movements of the inferior maxilla and partly by various manual manipulations. Part of the secretion, however, not infrequently remains in the auditory canal, thereby forming a plug which obstructs the canal and mechanically impairs the hearing.

Etiology.—The causes of accumulations of cerumen in the external auditory canal are: (1) Habitual or frequently recurring hyperæmia of the lining membrane of the meatus, which occasions a hypersecretion of its glandular elements. (2) Congenital or acquired strictures of the meatus which prevent the discharge of the secretion. To the congenital class belongs the tortuous course of the external meatus, while to the acquired class belong the membranous strictures, hyperostoses and exostoses in the external meatus, and the slit-like contraction of the external auditory orifice in old age, caused by atrophy and shrivelling of the cartilage. (3) Abnormal consistence of the cerumen, inasmuch as through the retention of a thick secretion, mixed with fine hairs of the cutis, an accumulation and storing up of the cerumen is favoured. (4) Improper cleansing of the meatus,

especially in persons who habitually allow a quantity of water or soap-suds to flow into the auditory canal while washing, and then forcibly insert a twist of the towel into the passage. The moistened cerumen is thereby forced from the cartilaginous into the osseous portion, and finally forms itself into a lump. (5) Eczema, circumscribed and diffuse otitis externa, partial or diffuse desquamative inflammations of the cutis of the meatus, and suppurations of the middle ear. After subsidence of the last-mentioned conditions a plug frequently forms, which, in such cases, is composed principally of epidermic masses. (6) Foreign bodies in the ear to which the cerumen adheres until an occluding plug is formed; in addition, collections of powder, coal-dust, portions of plants, etc.

Accumulations of cerumen may occur without any other disturbance in the ear, or may be combined with diseases of the middle ear and the labyrinth. In persons with normal hearing the plug may attain a considerable size before any impairment of hearing becomes manifest. These plugs, which are of the interstitial variety, do not completely fill the lumen of the meatus, and do not lie against the membrana tympani. A mechanical disturbance of hearing commences only when the lumen of the meatus is completely obstructed by the continuous accumulation of the secretion, or when the plug rapidly swells during washing, bathing, or through perspiring; and, lastly, when it is driven against the membrana tympani through a sudden jar (occluding plugs).

Symptoms.—Symptoms of an occluding ceruminous plug are: A feeling of discomfort and fulness in the ear, subjective sensations of sound, resonance of one's own voice, occasional attacks of dizziness and stupor in consequence of increased intra-auricular pressure, and in rare cases psychical depression, hallucinations of hearing, vomiting, attacks of eclampsia, blepharospasm, and facial paralysis. Only when the plug is very hard is a piercing pain produced as the result of pressure on the walls of the auditory meatus and on the membrana tympani. In such cases, after removal of the accumulated mass, one frequently finds a circumscribed inflammation of the osseous meatus, but rarely of the membrana tympani.

The disturbance of hearing varies considerably according to the degree of occlusion, and the apposition of the plug to the membrana tympani. The author has never observed total deafness, even in cases of complete occlusion. Therefore, where speech cannot be understood, we may assume with probability that a middle-ear or labyrinthine disease is also present. In idiopathic accumulations of cerumen the hearing distance often varies suddenly; this is especially the case when the plug swells and soon after rapidly contracts, or when it undergoes a sudden change of position owing to movements of the jaw. In per-

foration of the membrana tympani, the ceruminous plug may improve the hearing by acting as an artificial drum membrane.

Diagnosis.—By examination with the speculum, and not infrequently even with the naked eye, the meatus is seen to be plugged with a light yellow or dark brown greasy mass, which may be glistening or dull, and which, on being touched with the probe, feels doughy, half-liquid, or hard as a stone.*   The following may be mistaken for ceruminous plugs: Purulent or cholesteatomatous masses mixed with epidermis, which remain after an otorrhœa has run its course, and dry up to a brown crust; dried-up blood; foreign bodies enveloped in cerumen, and not infrequently balls of cotton which have worked their way inwards and have become brown with age.

Prognosis.—This is as a rule favourable, as far as the restoration of the hearing function is concerned, especially if the deafness has taken place suddenly, after bathing, while washing, or after one has freely perspired; when informed of this fact, the probable cause of the disturbance of hearing may be attributed to an idiopathic ceruminous plug.   Where this is not the case, one must be very careful in giving a prognosis, in view of the fact that accumulations of cerumen are very often associated with adhesive processes in the middle ear, or with diseases of the labyrinth. Lateralization of the tone of the tuning-fork during Weber's test towards the obstructed ear, or negative Rinne, must not be looked upon as a sign of an idiopathic ceruminous plug, as the same result is also obtained in middle-ear affections.   If, on the other hand, the tuning-fork, placed on the vertex of the head, is perceived by the better-hearing ear, it is very probable that there is a labyrinthine complication.   Yet, in exceptional cases, the tone can be lateralized towards the normal ear, even when an idiopathic ceruminous plug is present.   The bone perception is often, but not always, lengthened (Dundas Grant).

Treatment.—The ceruminous plug is most readily removed by forcibly syringing the ear with warm water.   For this purpose one employs a large syringe capable of holding 100–200 grammes; the plug is all the more easily removed if one attaches to the nozzle a short or a small rubber tube, rounded at the end, and inserts it as far as the plug.   Adherent ceruminous masses may first be loosened with a probe, and then removed by a forcible injection of water.

Careful syringing at the first examination is indicated only when the plug has a glistening, greasy appearance, and feels soft on being probed.   On the other hand, when the cerumen appears lustreless, dry, and hard, it is advisable first to soften it by the instillation of warm water or dilute glycerine; softening is best effected by means of a solution of soda and glycerine (sodii

* According to Kishe (*A. f. O.*, vol. lxx.), the cerumen of the Japanese is a white, dry, squamous mass, which is only occasionally slightly yellow.

carbon. 0·5, aquæ dest., glycerin. pur., ana 5·0); this solution should be used by the patient three to four times a day for several days. The cerumen is generally so softened and loosened after twenty-four hours that it can easily be removed after a few injections. If, after repeated syringing, the cerumen cannot be displaced, it is better to continue these instillations, as an otitis externa may be excited through frequent and violent injections. It must be mentioned that when ordering drops for instillation, the patient should be informed that the deafness might increase in consequence of swelling of the cerumen.

As a rule, the function of hearing immediately becomes normal, and the annoying subjective symptoms disappear after removal of ceruminous accumulations. It is only in exceptional cases that a slight deafness remains for a few days, and is due to the long-continued pressure on the membrana tympani, which quickly disappears when the latter has regained its normal tension. After the plug of cerumen has been removed, it is advisable to close the ear with cotton for several hours as a protection against cold.

In the majority of cases, after removal of the masses others reaccumulate. The interval between the re-formations varies from several months to several years. There are cases, however, in which the meatus becomes occluded with secretion in five or six weeks. The accumulation of cerumen is especially rapid in seborrhœa, and in such cases it is advisable to allow the patient to use instillations and injections at stated intervals.

A decrease or entire cessation of ceruminous secretion is not infrequently observed after an otitis externa diffusa or circumscripta has run its course, after eczema, and especially in connection with the insidious adhesive processes of the middle ear and in otosclerosis. The cause of this seems to lie in an affection of the trophic nerves of the ear, which accompanies the middle-ear disease. The secretion sometimes ceases in the acute middle-ear catarrhs, but frequently returns when an improvement has been brought about by treatment.* From this the assumption arises that the return of the ceruminous secretion is to be regarded as a favourable indication. This is contradicted by the fact that often during treatment of chronic adhesive processes in the middle ear an accumulation of cerumen occurs without a simultaneous improvement in the hearing. The secretion seldom completely ceases for any length of time if the external and middle ears are in a normal condition. The anomaly of cessation is mostly found in old people with a dry skin, and in those who habitually cleanse the meatus. In such cases the cartilaginous meatus appears free from cerumen, pale, and dull. The absence of ceruminous secretion is often accompanied by itching of a varying degree, and a feeling of dryness and contraction in the ear.

The treatment consists in occasionally painting the cartilaginous meatus with a small quantity of vaseline, with unguent. præcip. alb. (0·2 : 10), or with a mixture of tinc. nuc. vom. and glycerine (2 : 20).

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* Dundas Grant saw the reappearance of ceruminous secretion after the repeated use of Siegle's speculum.

The Diseases of the Skin of the External Ear.

The skin of the external ear may be the seat of a localized disease, or it may form part of a general cutaneous affection involving the entire, or large portions of the body. We will mention here only the cutaneous diseases which most frequently come under the notice of the otologist.

1. Hyperæmia of the External Ear.

Active hyperæmia of the auricle is caused either by mechanical irritation, or by the action of cold (frost) or heat; or it may be the remains of an engorgement of the cutis following an eczema and erysipelas; in some individuals it occurs after eating fish or after the use of certain drugs, as, for instance, antipyrin. Erythema exudativum multiforme, which, according to Hebra, is a true exudative process of the skin, may also be present on the auricle in all its stages, from a simple macular eruption to the development of the so-called herpes iris efflorescence; it is usually, however, part of a general erythema. Passive hyperæmia of the auricle is most frequently observed in cyanosis resulting from valvular lesions of the heart, and is a symptom of a venous stasis of the vessels of the head. A rare form of passive hyperæmia is observed as a local cyanosis, which is of an angio-neurotic nature, and is associated with blueness, turgescence, and a feeling of coolness of the auricle; it is met with in young individuals who are usually neuropathic or hysterical, and especially during puberty.

A congestive condition of the auricle, which is of a fluctuating nature, is observed in rare cases, and is to be regarded as an angio-neurosis of the sympathetic nerve. In these cases the hyperæmia is usually unilateral, less frequently bilateral. It appears especially in the evening, with great redness and a feeling of warmth and burning of the auricle, and is occasionally accompanied by tinnitus, heaviness of the head, and slight attacks of giddiness. This condition, which is usually transitory, and which returns at irregular intervals, sometimes appears in individuals with healthy ears, more frequently, however, in the course of adhesive middle-ear inflammations. For chronic hyperæmia, it is recommended to apply cold compresses saturated with a weak solution of liquor Burowii, with aqu. Goulardi, or with aqu. plumbica. We may also pencil the parts with tinctura rusci, followed by dusting with a cooling powder (such as oxid. zinci, carbon. plumbi, amyli oryzæ, ana 20·0, pulv. irid. florentin. 2·0), and anointing the auricle in the evening with vaseline; for the angio-neurotic form, the galvanic current applied to the sympathetic nerve of the neck is indicated.

Hyperæmia of the external meatus is a symptom which regularly accompanies hyperæmia and inflammation of the tympanic cavity and mastoid process. It often appears as a residuum of an inflammation of the auditory canal which has run its course, especially after eczema and furunculosis, and is also observed in association with congestion of the head, and with inflammations in the region of the ear, especially of the parotid.

The congestion is especially marked in the osseous, less frequently in the cartilaginous meatus, and extends, as a rule, to the upper parts of the membrana tympani and along the handle of the malleus.

Long-continued hyperæmia leads to a hypersecretion of the ceruminous glands, to abnormal desquamation of the epidermis, or to abnormal exudation with the formation of a crumbling, friable secretion.

2. The Inflammations of the External Ear.

A. Dermatitis of the Auricle.

Dermatitis of the auricle is most frequently caused by injury, frost-bite, and burns, but it may also be the result of a local parasitic infection. The affection not infrequently appears as a part of a severe erysipelas of the face and neck.

(a) **Dermatitis Traumatica.**—This form is due to the following causes: Thrusts, blows, falls upon the ear, insect bites, cauterization, scalding, piercing the ears, and the mechanical irritation of the cutis through the wearing of ear-rings which are too heavy or too tightly screwed. The extent, intensity and duration of inflammation depend on the severity of the injury. Such an inflammatory process may vary from the slightest form of a transient erythema to the development of a circumscribed gangrene of the skin. A severe local dermatitis, which may extend over the cutis of the entire auricle, may also be brought about by poisonous insect bites (bees, wasps, horse-flies, etc.). The treatment should be purely antiphlogistic, and is regulated according to the severity of the inflammation. The following lotions may be employed: Applications of cold aqua plumbi acetatis, or liquor Burowii diluted with 3 or 4 parts of cold water.

(b) **Dermatitis Erysipelatosa** (*Erysipelas auriculæ*).—This form of inflammation arises from erosions, excoriations, and injuries of the auricle and external meatus, and is brought about by the entrance of the specific bacteria of erysipelas (*Streptococcus erysipelatosus*, Fehleisen) into the injured parts. Its occurrence is facilitated by all forms of moist eczema, by erosions, maceration, and fissure formation of the cutis due to purulent discharge from the ear, and by any form of abrasion of the skin. Primary erysipelas of the auricle is rare; it occurs more frequently in combination with erysipelas of the face and head,

and occasionally extends to the external meatus and cavum tympani.

The inflammation usually extends over the entire auricle, and not infrequently involves the region surrounding the ear; the auricle itself is greatly reddened, swollen and enlarged, and the skin presents a stretched and shining appearance. Occasionally hard, dark red nodules in the skin or extensive bullæ are formed (*erysipelas bullosum*), which burst after they have existed a short time, and discharge a serous fluid. The affection is sometimes limited to the lobule. Brieger observed the extension of an erysipelatous inflammation from the external meatus to the tympanic cavity without a previous perforation of the drum membrane. Mygind reported a case in which the inflammation involved the labyrinth, and was followed by complete deafness.

Symptoms.—These are: High fever, a feeling of tightness in the head, dulling of sensation, severe burning, a feeling of tension and pressure in the auricle, shooting pains, and, later, continuous severe pain.

Course.—In the milder forms of this affection the fever and signs of inflammation subside in a few days, and the auricle regains its normal appearance. The author has seen, even when a number of bullæ were present on the auricle, healing take place within a few days after the bullæ had burst, inasmuch as the denuded places were quickly covered with normal epidermis. Adherent crusts occasionally form, and a marked redness remains for some time after they have been cast off.

In rare cases, in which the inflammation is very intense, flaccid, subcutaneous abscesses are formed. These occur especially on the posterior surface of the auricle, and if not opened at the proper time may lead to an extensive undermining of the skin of the auricle. A fatal termination from severe migrating erysipelas, or from gangrene, is a very rare occurrence.

Treatment.—The treatment of erysipelas of the ear should be conducted on antiphlogistic and antipyretic principles, the same as an erysipelas in any other part of the body. The following are often beneficial: 1 to 2 per cent. ichthyol, compresses of resorcin solution, ichthyol or resorcin collodion, Burow's solution, or compresses of pure alcohol.

(*c*) **Dermatitis Phlegmonosa.**—Phlegmonous dermatitis of the external ear is brought about by the entrance of the pyogenic bacteria into the injured cutis (*Streptococcus* and *Staphylococcus pyogenes*). It generally begins as a superficial dermatitis, and is often accompanied by severe fever. As a rule, however, it commences with heat, a sharply-defined redness and swelling of the skin, and presents the appearance of an erysipelas. The penetration of the inflammatory process into the deeper parts, and the subcutaneous formation of pus, are made evident by violent throbbing pain, and an increasing irregular swelling and

prominence of the auricle, accompanied by a doughy, soft feeling; the ear also becomes extremely sensitive within twenty-four to forty-eight hours, and a distinct fluctuation can often be perceived on the third or fourth day. The inflammation is aborted by extensive incisions made as early as possible at the point of fluctuation, and the wound treated antiseptically.

(*d*) **Dermatitis Congelationis Auriculæ.**—The skin of the auricle is specially predisposed towards this form of inflammation. This is explained by the fact that it is exposed to atmospheric influences, that it has a relatively thin cutis, and that the subcutaneous tissue, which separates it from the cartilage, is tense and scanty. All forms of dermatitis congelationis are observed on the auricle. The acute hypersthenic form, which arises from excessive cold, with a simultaneous freezing of the nose, may rapidly lead to partial necrosis and gangrene of portions of the skin and cartilage, with partial loss of the auricle; this is especially prevalent in the North. We also meet with the ordinary chronic form associated with moderate swelling and redness, and finally, the circumscribed, rather sharply-defined dermatitis—the true frost-bite.

These tissue changes lead to the formation of nodules and excoriations, especially on the elevations of the auricle—most frequently on the helix. They show little tendency to heal, and are sooner or later covered by crusts tinged with blood. After these have been cast off, desquamation of the skin often remains for a long time. Young chlorotic individuals, especially girls whose vaso-motor system is easily excited, are most often subject to this affection; it appears at a fixed time every year, at the beginning of the cold weather. It must be mentioned, however, that it is not necessary, in those predisposed, for the temperature to be below the freezing-point in order to bring about this form of dermatitis. It occurs more frequently in the low temperature of autumn, and especially if the patient has been exposed to atmospheric influences for a long time.

The following subjective symptoms are of importance: Lancinating pains which are experienced when the auricle is exposed to the open air, especially when the air is dry and the wind is severe; itching, burning, and a feeling of heat, which induce incessant rubbing and scratching, and which become almost unbearable in heated rooms and in bed.

Treatment.—The treatment in the acute inflammations consists in the local application of cold, which must be used as long as it is well borne by the patient. In the milder forms cold compresses with Goulard's solution, and tinc. opii (200·0 : 10·0), are sufficient; in the severer forms, a small ice-bag is indicated. In chronic and subacute dermatitis due to cold, washing and rubbing the ears two to three times daily with water as hot as

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can be borne is especially recommended. Besides the measures mentioned above, the physician should carefully pencil the parts twice a day with iodine collodion, as with this the unpleasant subjective symptoms are greatly relieved. For the latter, Bardeleben's collodium contra frigus (collodion 50·0, ol. ricini 2·0, ol. terebinth 7·5) has proved of value. Camphor ointments are also used with good results if applied several times a day (camphoræ rasæ 0·20, ceræ albæ 10·0, ol. lini 15·0), and greatly relieve the unpleasant itching. Where portions of the skin have been laid bare through the formation of bullæ or excoriations, they should be covered with an ointment of ung. hydrarg. præcip. ʒii., and ung. zinc. oxid. ad ʒi., and its application continued until the exposed area is again covered with a new resistant layer of epidermis. If the parts are very sensitive, a cocaine or powdered opium salve (5 to 10 per cent.) can be applied. Bing recommends pencilling the parts every evening with a salve consisting of calcaria chlorata 1·0, and ung. paraffini 9·0. Instead of the prepared ointments, Beiersdorff-Unna's zinc and boracic ointment mulls can be applied with great advantage in the above and all similar inflammations which are accompanied by the formation of crusts and excoriations, because they can easily adapt themselves to the elevations and depressions of the auricle and remain in position many hours. They should be reapplied morn'ng and evening.

We must still call attention to the occurrence of efflorescence on the auricle and in the external meatus arising in the course of herpes zoster and the acute exanthemata. The efflorescence in the external meatus appearing especially during the course of variola often leads to troublesome ulcer and crust formation. Dusting with boracic acid, and the introduction into the meatus of cotton tampons covered with boracic ointment, are most serviceable for the latter ailment. Orthoform vaseline and naphthalene have been recommended by some dermatologists.

B. Inflamations of the External Auditory Canal.

The cutis of the external meatus is always the seat of the primary forms of inflammation, and the changes produced here sometimes extend to its cartilaginous or osseous walls. The inflammation is either in the cartilaginous meatus, where the glandular elements of the cutis are affected, or in the osseous portion, from which the superficial diffuse inflammation often extends to the cutis of the membrana tympani. The external meatus is seldom uniformly inflamed in its entire extent.

Otitis externa presents a number of characteristic forms, the peculiarity of which depends partly on the situation and partly on the nature of the exudation and cause of the inflammation. Although we describe these various forms separately,

because they are clinically different, it must be mentioned that combined forms very often occur, making it difficult to classify a given case in a certain group.

1. Follicular Inflammation of the External Auditory Canal.

(*Otitis Externa Follicularis s. Circumscripta.*)

Follicular inflammation of the external auditory canal has its seat chiefly in the cartilaginous section. The process takes its origin either in a hair follicle or sweat-gland, or, as is often the case, a whole group of neighbouring follicles and glands is simultaneously affected. The seat of the inflammation is either that part of the cutis lying near the perichondrium, or its superficial layers.

Etiology.—Follicular inflammation, commonly known as furunculosis of the external meatus, often occurs without any known cause in healthy, robust individuals; sometimes it is a part of a general furunculosis. The formation of furuncles is observed in the course of chronic, purulent otitis media and chronic eczema of the external meatus. Other causes of this form of inflammation are: Mechanical irritation of the meatus, as frequent syringing and washing of the same; scratching with hard objects, as tooth-picks, hair-pins, etc.; injuries of the meatus; irritation caused by foreign bodies; and the instillation of irritating substances. The frequency with which furunculosis occurs in street-cleaners must be attributed to the dust.

Löwenberg found many micro-organisms in the furuncular pus, which, according to him, are the cause of the disease. The *Staphylococcus pyogenes aureus* and *albus*, which penetrate the hair follicle, have been proved to be the exciting cause (Schimmelbusch).* If the pus is discharged into the meatus, multiple furuncles may arise from the migration of the micrococci into other follicles; this explains the rapid recurrence of the furuncles.

Occurrence.—Furunculosis of the external auditory canal occurs especially in the spring and autumn, and in fact so often that one is inclined to look upon the affection as epidemic in character. It occurs more frequently in adults than in children, and is not infrequently observed in anæmia, in disorders of menstruation, in diabetes mellitus, and at the menopause.

Symptoms.—The symptoms vary according to whether the inflammation is situated in the neighbourhood of the perichondrium or in the superficial layers of the cutis. If the affection has its seat in the deeper layers of the cutis, the disease begins with gradually-increasing tearing or beating pains which radiate towards different parts of the head and neck; when the height

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* According to the investigations of Garré and Bokhardt, the different forms of furunculosis may be brought about experimentally by applying water which has been infected with the pure culture of *Staphylococcus pyogenes aureus*, and then rubbing it into the skin.

of the inflammation is reached, the pain is so severe that the patient is robbed of his sleep. Every time the ear is touched the pain is increased, and movements of the jaw especially increase the pain. Fever and loss of appetite are not uncommon in the first few days. A feeling of fulness in the head, subjective noises, and disturbances of hearing occur, as a rule, only when the lumen of the canal becomes blocked by the furuncle. These symptoms rarely arise if the canal is free, but, if present, they are due to a spreading of the hyperæmia to the middle and inner ear.

When the inflammation is deep-seated, the swelling, which is due to exudation, narrows the meatus, and appears flat, ill-defined, and only slightly reddened. If, on the other hand, the inflammation is seated in the superficial layers, we find a very red, livid, sharply-defined elevation which often develops with slight pain, and sometimes without any at all. The inflammation is most frequently located on the inferior and posterior walls of the meatus, and on the inner surface of the tragus. Multiple furuncles often arise simultaneously, or rapidly succeed each other, whereby the lumen of the canal is closed through their mutual contact. When they form in the anterior wall, the parts in front of the tragus appear swollen and of a bluish-red colour; when they are situated on the posterior wall, the swelling on the mastoid is sometimes so marked that it may be mistaken for a periostitis mastoidea. The author has seen cases in which a fluctuating abscess on the mastoid process was due to a furuncle on the posterior wall of the meatus. After this had been incised from the external auditory canal the pus was discharged, and after the application of a pressure bandage healed in a few days. After rupture of the abscess, Krebs found (*Therap. Monatschr.*, 1907) that in many cases the bone was secondarily affected. Coincident glandular swellings on the lateral region of the neck are, on the whole, rare. Follicular abscesses at the inner portion of the cartilaginous and at the beginning of the osseous meatus usually appear as yellowish-green pustules, about the size of a hemp or millet seed, on the posterior and superior walls.

Course.—In the majority of cases, the exudate becomes purulent after the inflammation has existed four to five days. It sometimes takes eight to ten days for the abscess to form. The abscess usually breaks at the yellow apex, where it points; rarely at the side. If the exudate is deep-situated, the greater will be the delay in the discharge of the abscess into the auditory canal. The inflammation seldom subsides without the formation of an abscess.

As a rule, the violent pain ceases on spontaneous or artificial opening of the abscess, and the other symptoms also gradually subside. Sometimes, however, violent exacerbations occur, which are due either to the formation of new abscesses at

other parts of the meatus, or to the occlusion of the abscess opening, which prevents the escape of the pus.

When the abscess drains freely, the swelling subsides in a short time; still, slight infiltration and elevation often remain for some weeks. Spongy granulation tissue often projects from the orifice of the abscess, and may be mistaken for a fungiform polyp on the wall of the canal. The course is always protracted by such growths, and cure is effected only after their removal with a curette or cautery.

Furunculosis of the auditory canal shows a special tendency to relapse. It appears either spontaneously or after mechanical irritation, especially in diabetic patients, and recurs sometimes at shorter, sometimes at longer intervals (habitual furunculosis), often causing emaciation and nervous excitement.

Diagnosis.—This is not difficult, if we take into consideration the subjective and objective symptoms. If the examination is carried out perfunctorily, exostoses in the external meatus covered with reddened cutis, and bulgings of the wall, which develop in the course of a mastoiditis, may be mistaken for furuncles. On the other hand, a diffuse furunculosis extending from the external auditory canal over the mastoid region may be mistaken for a true mastoiditis. It is therefore often difficult to arrive at a correct diagnosis at the first examination. As a rule we can conclude that we are dealing with an affection of the canal by the absence or slight rise in temperature, and by the result of our treatment. In a true furunculosis of the canal the inflammatory process yields to treatment within a short time, while in a true bone involvement of the mastoid the tenderness and swelling persist, and are relieved only by operative measures. In the osseous section of the auditory meatus in which the glandular elements are wanting, single or multiple pustules sometimes develop, causing severe pain; this condition, however, does not belong to the category of follicular inflammations.

Treatment.—In the stage of exudation, our aim is to relieve the pain as quickly as possible. This is most readily accomplished with hot applications in the form of wet dressings, hot-water bags, or the electric pad. The best results are obtained with hot dressings or Burows solutions in the proportion of one part of the solution to three or four parts of hot water. A small gauze wick saturated with the hot mixture should be gently introduced into the swollen external meatus as far as possible, and sterile gauze saturated with the solution applied around the posterior surface of the auricle and over the entire external region of the ear. These wet dressings should be continued until the deep-seated abscess comes to the surface, whereupon the furuncle, as a rule, bursts spontaneously. In the majority of cases, these hot dressings bring about a rapid relief of the pains, and cause a subsidence of the inflammatory swelling within a few days. In other cases, the writer

has obtained some relief and an alleviation of the condition by the liberal application of pure ichthyol to the swollen canal. Where in spite of these conservative treatments the swelling and pain persist, one is occasionally called upon to resort to operative measures by making free incisions into the swollen mass. The operation can be performed with or without a local anæsthetic, or under a general anæsthesia of ethyl chloride or gas. In cases in which pus has not formed, a sanguineous fluid will be discharged through the incision, and the pain will thereby be alleviated by relaxation of the cutis. If the pus is not reached by the incision, it very soon makes a way for itself into the opening. Incision is furthermore indicated when the pus has reached the surface and the swelling has come to a point, but has not burst on account of the strong resistance of the epidermic layer. Even in those cases in which the abscess has opened spontaneously, but in which the discharge of pus is hindered on account of the smallness of the opening or by the ' core ' of the furuncle, it is often necessary to enlarge the opening. After spontaneous or artificial opening of the abscess, it is advisable to exert moderate pressure on the external surface of the cartilaginous meatus in order to bring the pus and the core to the surface.

Other remedies besides incision may be employed to alleviate pain. The following may be mentioned: Narcotic embrocations around the ear (*vide* Treatment of Acute Middle-Ear Inflammation); the introduction into the auditory canal of little plugs of cotton or gauze dipped into a mixture of aq. opii 4·0, aq. dest. 12·0, or into a 5 per cent. cocaine solution. Small pledgets of cotton dipped in a 2 per cent. solution of resorcin are very good. By the use of these, small furuncles may subside and large ones may become smaller and perforate more easily. The pain is furthermore relieved by the insertion of a long strip of gauze covered with a morphine boracic acid salve (acid. boric. 1·0, vaselin. 20·0, acet. morph. 0·2). The author has seen rapid relief follow the application of Leiter's tubes through which cold water was allowed to flow (*vide* Treatment of Inflammation of the Mastoid Process). Syringing the ear is to be avoided, as experience has shown that it may give rise to new eruptions.

A considerable improvement in the treatment of furunculosis of the external meatus has been achieved through the introduction of antisepsis. The most effectual remedies are: Carbolic acid in the form of carbolic glycerine (0·5 : 15·0), which may be applied with a brush, or introduced into the auditory canal by means of a piece of cotton saturated with the same; boracic acid (Morpurgo), which may be used in the form of powder, or in the form of an alcoholic solution in the proportion of 1 : 20. All these remedies may be employed before or after opening of the abscess. The author has repeatedly seen a recession of the furuncles, without bursting into the meatus, after painting with carbo-

glycerine. When they recur repeatedly, one can resort to the stronger antiseptic instillations of bichloride of mercury and alcohol (hydr. bichlor. corros. 0·05–0·1, spirit. vini rectif. 50·0, Kirchner).

After the furuncle has been incised, the opening should be immediately disinfected with carbo-glycerine, or with a solution of boracic acid and alcohol; this is done to check the growth of the cocci, and to prevent the bacteria from migrating into the neighbouring follicles.

After-treatment.—After the follicular inflammation has run its course, it is advisable to give instillations of boracic acid and alcohol in a 25 per cent. solution, three to four times a day, until the canal has assumed a normal appearance. The ceruminous secretion either ceases entirely or there remains a crumbling scaly exudate. This abnormal discharge is usually accompanied by severe itching, causing the patient to scratch the meatus with all kinds of hard bodies.

To prevent this troublesome itching it is recommended to anoint the cartilaginous meatus every second day for several weeks, after the disappearance of the furuncle, with a white precipitate ointment (hydrarg. præcip. alb. 0·3, ung. emoll. or vaselin. 12·0), or with a boracic ointment (1 : 20 vaseline or lanoline), to which a little cocain. oleinicum (5 per cent.) or anæsthesin (1 : 20) may be added. Pencilling with boracic alcohol (1 : 20), or with an alcoholic solution of epicarin (1 : 20), or with a concentrated solution of picric acid, usually relieves the troublesome itching. The entrance of water into the meatus while washing or bathing is the cause of frequent relapses.

2. Diffuse Inflammation of the External Auditory Canal.

(*Otitis Externa Diffusa.*)

There is no doubt that the pathogenic micro-organisms are mainly responsible in bringing about diffuse inflammation of the external meatus. This is also caused by the instillation or injection of irritating substances, or by the action of traumatic influences. The author has repeatedly seen an infectious, diffuse inflammation of a phlegmonous character follow excoriation of the cutis of the meatus. This form often shows a desquamative character, a genuine purulent inflammation of the external meatus being seldom observed.

Symptoms.—The symptoms of otitis externa diffusa are especially marked in the osseous meatus, and on the external surface of the membrana tympani. The inflammation begins with marked hyperæmia and painful swelling of the cutis, which is followed in a few days by a serous or viscid exudation. The author has quite often observed, especially during influenza epidemics, the formation of an exudate resembling a solid, trans-

parent, gelatinous plug. On examination, the constricted meatus and the external surface of the membrana tympani are found to be covered with a white layer of epidermis; this peels off during syringing, coming away as a cast of the canal. The author found on microscopic examination that these scales contained large numbers of micrococci, which demonstrates the bacterial nature of the affection. After the removal of this cast, the cutis of the meatus and the membrana tympani appear markedly reddened and swollen, the parts of the malleus are invisible, and the boundary between the membrane and auditory canal is obliterated. Sometimes the meatus is so constricted by a 'diffuse swelling or a simultaneous follicular inflammation of its cartilaginous section that it is impossible to inspect the deeper parts.

The subjective symptoms of otitis externa are violent, radiating pains which increase when pressure is applied in the region of the ear, and on movement of the jaw; sometimes subjective noises and a feeling of tightness in the head are also complained of.

The hearing is normal or slightly impaired. A high degree of deafness may be present only when the cutis of the membrana tympani is greatly swollen, when there is an accumulation of exudate and epidermic scales in front of the membrane, and in cases of secondary swelling in the middle ear.

Course and Termination.—In some cases the crisis of the disease is reached on the third day; in others, the course is irregular, inasmuch as the symptoms of recession are alternated by repeated exacerbations, increased exudation, and desquamation of epidermic scales. Only when the secretion ceases and the meatus becomes dry can we assume that the inflammatory process has come to an end.

This form of inflammation, as a rule, terminates in recovery, with complete restoration of the hearing. Still, subjective noises and deafness may remain for some time after the cessation of the inflammation. The author has seen, in rare cases, circumscribed ulcerations and perforations of the membrana tympani develop after the acute stage had run its course, in addition to circumscribed ulcerations on the inferior wall of the osseous meatus with exposure of the bone, and the formation of granulations in the exposed area.

Transition into the chronic form is rare. It generally runs its course without pain, often with intense itching, and sometimes with subjective noises and deafness. The discharge is seldom profuse; it is generally of a thick, offensive, greasy nature, and contains, in addition to epidermic and pus cells, many micrococci. After cleansing the meatus, the osseous section is found to be swollen, and one or more granulations the size of hemp-seeds are not infrequently seen on its posterior superior wall, and occasionally on the cloudy membrana tympani. Such growths may lead to the formation of bands of connective tissue by apposition and

ultimate adhesion. A fibrous polyp, filling the entire meatus, sometimes develops in the course of a chronic inflammation of the osseous section, after the removal of which the membrana tympani appears intact. As a rule, the secretion ceases completely one to two days after the removal of such polypi, and the hearing returns to its normal state. A chronic desquamation occasionally remains.

In the idiopathic form the author has, in rare cases, seen the inflammation terminate in hypertrophy of the cutis; in periostitis and hyperostosis, with contraction of the meatus; in ulceration, caries, necrosis, and exfoliation of flat plates of bone from the walls of the meatus; in extension of the inflammation to the parotid, to the mastoid, the cranial cavity, or to the sigmoid sinus. These changes are more often observed in the syphilitic and traumatic, and in those secondary inflammations of the meatus which arise in the course of chronic otitis media.

Diagnosis.—The diagnosis of primary otitis externâ can be made with certaińty only when the view of the walls of the meatus and the membrana tympani is uninterrupted, and when a middle-ear suppuration can positively be excluded. It is more difficult when the auditory canal is greatly constricted, and when there is a co-existing follicular inflammation, as this condition is often combined with diffuse swelling of the walls. In order to complete the diagnosis, the cast-off epidermic scales must be microscopically examined for micrococci or for the aspergillus fungus.

Prognosis.—The prognosis of idiopathic otitis externa is favourable, as not only do the acute forms generally subside without after-effects, but even in those chronic cases in which granulations or large polypi have developed, cure takes place after their removal. The prognosis is less favourable in the traumatic inflammations, and in those caused by corrosion of the walls, as these lead to stricture and atresia of the meatus. A fatal termination through caries of the osseous meatus and extension of the process to the cranial cavity or lateral sinus is of rare occurrence.

Treatment.—In the acute inflammations, as long as the reactive symptoms continue, the same palliative treatment is indicated as that which will be described in detail in the chapter on Acute Inflammations of the Middle Ear. In the idiopathic forms, when the inflammation is very severe, we must resort to antiphlogistics in the form of cold wet dressings and ice-bags. Local antiseptic treatment must be begun immediately with the commencement of marked secretion, and with the shedding of epidermic scales. After irrigating the ear it is almost always possible, in acute cases, to stop the secretion by frequently insufflating finely-powdered boracic acid into the meatus. The latter medicament may also be first tried in chronic cases in which

the swelling is not severe, and in which there are no granulations in the auditory canal. If the boracic acid proves ineffectual after its application for several days, we should then use instillations of boracic alcohol (1 : 20), boracic glycerine, sublimate alcohol (0·05 : 50), or iodol alcohol (1 : 20). In obstinate cases, this method of treatment proves effectual only after repeated cauterizations with strong solutions of silver nitrate or with the solid stick. The ear should be closed with sterilized cotton after each application. Where ulcers exist which, in spite of the most careful antiseptic treatment, show no tendency to heal, they should be cauterized several times with solid nitrate of silver, the parts being previously anæsthetized with powdered cocaine.

We must still mention the desquamative inflammations of the meatus, which mostly run a chronic course, and lead to the formation of cholesteatomatous masses in the auditory canal. The molluscous tumours of Toynbee and the keratosis obturans of Wreden (*A. f. A. u. O.*, vol. iii.) may be placed in this class. These cholesteatomatous masses of the external meatus are seldom the product of an acute otitis externa ending in an exuberant desquamation; they are more often the sequelæ of a chronic desquamative process which runs its course without symptoms, and which, as the author has repeatedly seen, may lead to atrophy of the cutis and absorption of the osseous walls. In a number of cases observed by the author at the *post-mortem* he found the meatus filled with a white, lustrous, cholesteatomatous mass which extended to the membrana tympani; this affection was bilateral in most cases, and there were no simultaneous changes in the cavum tympani. In the majority of specimens the lumen of the meatus was markedly enlarged, and either the posterior superior wall was hollowed out, or the anterior wall was thinned or broken through with a large defect in the bone.

3. Otitis Externa Hæmorrhagica.

This is characterized by a hæmorrhagic effusion into the osseous, seldom into the cartilaginous, meatus, and is accompanied by more or less well-marked reactive symptoms. It usually occurs in young persons without any known cause, and commences with moderate pain, tinnitus, and slight deafness; it is commonly seen in influenza. Examination reveals one or more dark blue elongated swellings in the osseous meatus, which are situated on its inferior, more rarely on its posterior, wall; these often extend to the posterior inferior segment of the membrana tympani, and to the cartilaginous meatus. Through their swelling they narrow the lumen of the canal to such an extent that it is impossible to view the drum. In such cases, we are dealing with a superficial inflammation of the cutis, in which the epidermis is raised to a considerable extent by the hæmorrhagic exudate. Upon probing, the blue swellings feel very soft and rupture even under very slight pressure, whereupon a sanguineous fluid is discharged. According to the author's observation, it occurs very often as a concomitant symptom of the acute otitis of influenza.

The climax of this form of inflammation is usually passed on

the third day. The hæmorrhagic vesicles may remain for several days after the disappearance of the reactive symptoms, until their contents is discharged by spontaneous rupture or is absorbed. After the disappearance of the vesicles, others often appear in other parts of the meatus. This disease may be confounded only with the hæmorrhagic bullæ produced traumatically by rarefaction of the air in the external meatus or with livid polypi.

Termination.—Otitis externa hæmorrhagica always ends in recovery; after eight to fourteen days the elevated epidermis of the meatus and of the membrana tympani is cast off in large scales, the diseased parts become covered with a delicate, dry, epidermic layer, and the hearing returns to its normal state.

Treatment.—This consists in opening the vesicles and wiping out the secretion with sterilized gauze or cotton. Thereupon the auditory canal is insufflated with finely-powdered boracic acid, which is repeated until the powder remains perfectly dry for twenty-four hours. As a rule, it is necessary to apply the powder only three or four times.

4. Croupous and Diphtheritic Inflammation of the External Auditory Canal.

(Otitis Externa Crouposa et Diphtheritica.)

Otitis externa crouposa is one of the rarest forms of disease of the external auditory canal. Mention is made of this form of inflammation by Wilde and other authors, who sometimes found the meatus and the membrana tympani covered with a layer of lymph similar to that observed in the trachea during croup. In a case of croupous exudation on the tonsils, Gottstein saw a croupous membrane firmly adherent to the posterior wall of the osseous meatus, after the removal of which the excoriated surface bled easily. Steinhof (*Inaugural Dissertation*, 1866) reports thirty cases, and Bezold eleven (*Virchow's Archiv*, vol. lxx.). The fibrinous exudate is confined only to the osseous portion of the auditory canal, and to the external surface of the membrana tympani. It seldom occurs independently, but usually appears after an acute otitis media has run its course, or with furunculosis of the auditory canal. The fibrinous membranes form within one to two days, and may be loosened from the underlying tissue by moderately strong injections; they come away as solid, firm casts of the osseous meatus and of the membrana tympani, and in appearance are not unlike cooked bacon. According to Steinbrügge, the exudate is composed of a fibrous network infiltrated with round cells, nuclei, and epithelium. Guranowski (*M. f. O.*, 1888) described a case in which he isolated the bacillus of green pus from the membranes; Löwenberg succeeded in isolating the *Streptococcus pyogenes*, and Weichselbaum the *Staphylococcus pyogenes albus*.

The inflammation usually affects healthy individuals, and develops with moderate pain; this becomes more severe with the commencement of the fibrinous exudation, and usually subsides when the membrane is cast off. The exudation may recur repeatedly; still, cure almost always takes place without any other complication and with complete restoration of the hearing.

Prognosis.—The prognosis of this form of inflammation is favourable, as recovery usually takes place within a few days without any unpleasant sequelæ. Termination in gangrene of the cartilaginous meatus has been observed, but is fortunately rare.

Treatment.—This consists in the removal of the croupous membrane by means of antiseptic injections or with the forceps, and of dusting the parts with powdered boracic acid.

Otitis externa diphtheritica, usually combined with diphtheria of the auricle, seldom appears primarily, but is generally complicated with diphtheria of the pharynx and of the middle ear. According to Moss, Wreden, and Kraussold, primary diphtheria of the meatus develops during an epidemic of diphtheria on the excoriated parts of the auditory canal from an already existing otitis externa. Blau reports a case in which he saw a diphtheria of the pharynx develop from a primary croupous inflammation of the external meatus.

In primary as well as in those diphtheritic inflammations of the meatus complicated with diphtheria of the middle ear, the walls of the auditory canal appear covered with a dirty grayish-white exudate, which cannot be removed by syringing or with the forceps. After the exudate has been forcibly loosened by means of the probe, the wall of the meatus appears excoriated, ulcerated, and bleeding. Even the slightest touch on the ulcerated parts is extremely painful. The meatus is sometimes so narrowed that it is possible to inspect its deeper portions only after removal of the membranous deposit. The region surrounding the ear is red and swollen, and the lateral cervical glands, as well as the lymphatic glands behind the ear, are likewise affected. The primary form of this inflammation, which begins with moderate secretion, is accompanied by fever, severe pain, feeling of fulness, tinnitus, and deafness; on the other hand, that form of inflammation associated with diphtheria of the middle ear runs its course almost without pain, and is accompanied by anæsthesia of the region of the ear.

Course.—Diphtheritic inflammation of the meatus has an uncertain course. Sometimes the exudate is rapidly thrown off, but often, however, it remains adherent for a long time; or repeated exudations take place either on the parts already affected or on other portions of the meatus. In a case of diphtheria of the middle ear and meatus described by Blau, the affection extended to the auricle, giving rise to deep cutaneous ulcers.

Termination.—Diphtheritic inflammation of the meatus terminates without any permanent changes if the seat of the exudation is superficial; if, on the other hand, the affection is deeply seated the cutis ulcerates, and the ulcers, which remain for some time and are easily made to bleed, finally heal by cicatrization, with narrowing and adhesion of the walls of the meatus.

Diagnosis.—The diagnosis of this inflammation can be established with certainty only by the microscopic examination and culture of the peculiar adherent membrane, and if, after its removal, an ulcerated, bleeding surface is exposed. The diagnosis can be made with more certainty if an epidemic of diphtheria is prevalent, and if there is a simultaneous suppuration of the middle ear with a naso-pharyngeal diphtheria. The white exudate which is seen in children, and which occurs during the course of an acute scarlatinal suppuration of the middle ear, must not be confounded with diphtheria of the meatus; such an exudate is due to maceration of the epidermis, and extends to the external orifice of the ear. It differs from diphtheria in that it is easily peeled off in large flakes. To verify the diagnosis it is important to make a culture of the adherent membrane for the presence of diphtheritic bacilli.

Prognosis.—The prognosis of primary diphtheria, if confined to the meatus, is, on the whole, favourable. It is unfavourable, however, if complicated with diphtheria of the pharynx and middle ear, inasmuch as a high degree of deafness generally remains; this is due to the simultaneous extensive destruction of the membrana tympani, to the frequent exfoliation of the ossicles, to the consecutive caries, and to the occasional occurrence of a labyrinthine affection.

Treatment.—The treatment of otitis externa diphtheritica is strictly antiseptic. If the case has been proven to be a true diphtheria from cultures made from the membrane in the ear, it is advisable to give diphtheria antitoxin, just as in a diphtheria of the nose and throat. In the primary forms it is advisable to fill the meatus with lime-water from time to time, in order to favour the loosening and separation of the diphtheritic membrane. After the fluid has been allowed to remain fifteen to twenty minutes, the meatus should be syringed with a weak solution of boracic acid, and then dusted with finely-powdered boracic acid or iodoform. If, after this treatment, the membrane is repeatedly formed, the affected parts should be touched with carbo-glycerine (1 : 15) or carbolic alcohol (1 : 20); in addition, the meatus should be filled several times a day with an alcoholic solution of boracic acid (1 : 10), or with a weak solution of salicylic alcohol (1 : 100), or of bichloride alcohol (0·05 : 50·0).

5. Parasitic Inflammation of the External Auditory Canal (Mycosis of the External Meatus).

(Otomycosis [Virchow]—Myringomycosis aspergillina [Wreden].)

A few cases of fungus in the ear had already been observed by Mayer,[*] Pacini,[†] and Karl Cramer.[‡] The attention of otologists was drawn to otitis externa parasitica by a short paper of Schwartze (*A. f. O.*, iii.), and especially by an exhaustive work of Wreden (*Monograph*, 1868). The pathology of otomycosis has been furthered by the valuable contributions of Blake, J. Patterson-Cassels, Hassenstein, Hagen, Bezold, Steudener, Löwenberg, Wagenhäuser, and Siebenmann.

The most common fungi met with in the ear belong to the species Aspergillus niger (van Tighem), flavus (Brefeld), and fumigatus (Fresenius). The following are more rarely seen: The Vesticillium Graphii (Trichothecium roscum), observed by Steudener; a fungus with grass-green conidia (Otomyces Hageni), described by Hagen; the Aspergillus nidulans; the Ascophora elegans of von Tröltsch; the Mucor corymbifer of Lichtheim, first observed in the

FIG. 96.—ASPERGILLUS NIGER.

a, Mycelium covered with numerous fallen spores; *b*, Hypha; *c*, Sporangium, with ripe spores; *b'*, Hypha; *d*, Receptaculum; *e*, Sterigmata with spores.

auditory canal by Wagenhäuser; the Eurotium malignum of Lindt and Siebenmann; the Mucor septatus and the Penicillium minimum.

Examination of the fungous mass removed from the ear reveals a felt-like, stratified, mycelial structure, intermixed with cast-off epidermis, from which small, cylindrical stalks (hyphæ, Fig. 96, *b*, *b'*) arise, the walls of which are rather thick; these stalks support the head of the fungus (sporangium or fruit-capsule, *c*). The latter consists of a central vesicular enlargement (*d*), (receptaculum), from which long cells radiate (sterigmata, *e*), and having round conidia or spores at their free extremity.

The colour of the various forms of fungi depends partly on that of the conidia. They are blackish-brown in the Aspergillus niger, yellowish or greenish in the Aspergillus flavus and in the Aspergillus glaucus, and grayish-black in the Aspergillus fumigatus. According to Burnett, the fructification heads are smaller and narrower in the Aspergillus glaucus than in the Asper-

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[*] Müller's *Arch. f. Anat.*, etc., 1844.　　　　　[†] Firenze, 1851.
[‡] *Vierteljahrsschr. d. naturf. Ges.*, in Zürich, 1859 and 1860.

gillus niger; the Aspergillus fumigatus possesses the smallest sporangium, which, according to Bezold, more rarely occasions inflammations in the ear than the other species. The Mucor corymbifer is distinguished by the umbel-shaped arrangement of the sporangium-bearers, the small, colourless, pear-shaped heads, the brownish, twisted columellæ, and the very small, colourless, elongated spores.

Etiology.—The spores which enter the meatus from without can, under favourable circumstances, germinate and rapidly increase. If all the conditions are favourable for their growth, they can develop all the more easily in the meatus, as here they are protected from every mechanical influence. The growth of the fungus is most often accelerated by the instillation of oily substances, which, like all fats, form a very nutritive soil for their development. Fungi are often developed in the ears of persons residing in damp, mouldy localities. The source of infection of otomycosis is very often unknown.

Occurrence.—Otomycosis, running its course with reactive phenomena, usually occurs in middle-aged adults, seldom in children or old people, and is more common among the poor than among the rich. The frequent development of fungi in individuals affected with middle-ear catarrh certainly depends on the frequent instillations of easily decomposing substances into the meatus. In chronic suppurations of the middle ear, fungous growths often develop on moist scabs, without causing any inflammatory phenomena. Burnett and Bezold have seen cases in which the fungus extended into the tympanic cavity. In one of the author's specimens, the mycelia could be seen to penetrate the tissue of the membrana tympani. In a case observed by Haug (*Ziegler's Beiträge zur pathologischen Anatomie*, etc., xvi., 1894), in which the mastoid process was opened, the cell-spaces contained fungi which had forced their way in from without.

Symptoms.—Fungi in the auditory canal may exist without any symptoms, even if they extend over a great part of the meatus and of the membrana tympani; this is especially the case if the fungus has its seat only in the epidermis. When, however, the vegetations penetrate the *rete Malpighii*, that peculiar form-of inflammation is developed which is known as otitis externa parasitica. In two cases of aspergillus observed by the author, which ran their course without symptoms, a severe mycotic inflammation arose after a slight abrasion of the meatus.

The subjective symptoms of otitis externa parasitica are severe itching and shooting pains. The latter often become violent, and radiate towards the head and neck. In addition to these, we find, in the majority of cases, tinnitus and deafness.

If we examine the auditory canal in a case of Aspergillus niger, we find the membrana tympani. and especially the osseous meatus, covered with a velvety membrane marked with black spots or uniformly black, and having the appearance as if it

had been sprinkled with fine coal-dust. On syringing, this membrane is washed out in large threads of considerable thickness, on the surface of which the characteristic black spots (sporangium) are visible, even to the naked eye. These spots are sometimes scattered, sometimes closely packed. The surface of the membrane lying in contact with the osseous wall is of a whitish or dirty-gray colour. According to Löwenberg, small cysts may form on the epidermis, on the inner surface of which the fungi are seated; these may rest against the membrana tympani and become infiltrated with mycelia. In cases of Aspergillus flavus, the epidermis, invaded with mycelia, appears covered with a yellowish mass of dust, similar to powdered lycopodium.

After removal of such membranes from the meatus, the lining membrane of the osseous section and of the membrana tympani appears very red, swollen, and in great part devoid of its epidermic layer. We see only here and there solitary, irregular patches of epidermis penetrated by spores. Where the fungus develops without inflammation of the walls of the meatus, the black or yellow growth is seen extending over a portion of the osseous meatus. In such cases, the hyphæ and sporangia are visible even to the naked eye, or with the aid of a weak lens.

Course and Termination.—The course of otitis externa parasitica depends on the extent of the growth, and whether treatment is begun early or late. When the affection is allowed to run its course, or is treated by a physician who does not know its nature, the inflammation may continue for several weeks with only a slight change, or may even lead to a perforation of the membrana tympani. Notwithstanding the fact that the parasitic growths remain in the ear, the inflammation sometimes ceases completely, only to reappear with renewed vigour at intervals of weeks or months. On examining such cases, we often find the meatus completely filled with closely-packed fungous membranes.

Immediately after syringing out the membrane there is, in the inflammatory stage, a diminution in the pain and subjective noises, and cure rapidly ensues if the proper treatment is employed. If, however, after the removal of such membranes no antiparasitic remedy is used, we often find, even on the following day, the meatus covered with a thick membrane similar to that already removed, and a continuation of the reactive symptoms. Relapses may thus rapidly occur, until the fungus is either cast off spontaneously or cure takes place through treatment.

Diagnosis.—The diagnosis of this affection presents no difficulty if marked symptoms of an otitis externa are present, and if the examination with the speculum shows the characteristic objective symptoms described above. Sometimes, however, blackish-brown epidermic scales are syringed out of the ear, which may be mistaken for fungous membranes. This colour is due to the accumulation of dust, coal-dust, or finely-powdered

vegetable *débris*. In every case, therefore, a microscopic examination is indispensable in order to establish the diagnosis.

Prognosis.—This is always favourable, as a rapid cure is effected by the use of parasiticides; even after perforation of the membrana tympani, cicatrization of the aperture takes place in a short time. The prognosis is not so favourable, however, in persons who dwell in damp, mouldy localities, as in such cases there is always a possibility of a recurrence of the inflammation. The author has, however, seen frequent relapses in persons whose conditions of life were most favourable, and where the cause of the recurrence could not be accounted for.

Treatment.—Alcohol, recommended by Hassenstein and Küchenmeister, has proved most serviceable in the removal of fungous growths. After the greater part of these membranes has been removed by syringing, the meatus is filled with slightly warmed alcohol, which is allowed to remain for at least a quarter of an hour. This procedure should be repeated twice a day at the beginning of treatment. As a rule, the alcohol is well borne. When it causes a severe burning, it is advisable to dilute it with distilled water, and gradually to increase its strength until the patient is able to stand the full strength. In very obstinate cases, the author has seen a rapid cure follow the instillations of an alcoholic solution of bichloride (0·05–0 1 : 50·0).

The treatment generally responds so rapidly that, even after two days, no sign of the fungous growth is visible in the meatus. The lining membrane of the auditory canal and of the membrana tympani appears covered with a dry, delicate layer of epidermis; the pain, tinnitus, and deafness disappear; and, after three to four days' treatment, the cure is almost complete.

Relapses are best prevented by allowing the patient to continue the instillations of the alcohol from time to time; this should be carried out at least once every four weeks.

Besides alcohol, other remedies have been recommended for the destruction of the fungi. The following are the most effective: Powdered boracic acid alone, or in the form of an alcoholic solution (1 : 20); permanganate of potassium in 0·6 per cent. solution (v. Tröltsch, Schwartze, Hagen); carbolic acid (3·0 : 100·0 oil or glycerine, Lucae); alcoholic solution of salicylic acid (2 per cent., Bezold); pyoktanin powder (Rohrer); and, finally, hyposulphite of soda (0·2 : 30·0, Blake, Burnett).

We must still mention a rare form of mycosis known as pityriasis alba, and described by Ladreit de Lacharrière (*Annal. des mal. de l'oreille*, etc., 1875). It occurs in combination with pityriasis capitis between the ages of forty and fifty. After removal of the small scales, which under the microscope show the characteristic fungous spores, the cutis of the meatus appears thick and red. This form of mycosis is not to be confounded with seborrhœa of the external auditory canal. In the latter disease there is also a yellowish-gray secretion, mixed with fatty scales, without any noticeable changes in the cutis. The treatment of pityriasis alba consists in the extraction of the stiff hairs, and in painting the meatus with a 0·5 per cent. solution of corrosive sublimate. Albesby described two cases of pityriasis. Kirchner observed a transmission of pityriasis versicolor from the breast and neck to the external meatus, where

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it produced only a troublesome itching. Lang saw dermatomycosis favosa and circinata on the auricle. The former cannot very well be mistaken, while the latter, however, may be confounded with an annular syphilide if combined with a similar affection of the neck. Barnick has written on the subject of ecthyma of the auricle. The author has repeatedly observed cases of psoriasis of the auricle accompanying a similar affection of the whole body.

C. Eczema of the External Ear.

Eczema of the external ear occurs either as a primary affection or combined with eczema on other parts of the body. Its course is either acute or chronic.

Acute Eczema.—This affection may be localized either on the auricle or in the external auditory canal, or it may involve the whole external ear. It begins with great redness and swelling of the skin, which is soon followed by the formation of numerous closely-clustered vesicles containing a serous fluid (eczema vesiculosum). The eruption is mostly found on the posterior surface of the auricle and on the lobule; the entire auricle is seldom affected. The vesicles are rarely visible in the auditory canal and on the drum membrane, on account of their early destruction.

After rupture of these vesicles, moist surfaces, denuded of epidermis, are seen on the auricle and in the meatus. In a few days these become covered with a light yellow crust (eczema crustosum), under which the exudation of a serous or viscid fluid still continues. Pustules the size of a bean are sometimes formed, accompanied by marked inflammatory phenomena. When these burst, thick crusts are formed under which the purulent secretion is confined (eczema impetiginosum). According to Rohrer, the serous secretion contains diplococci, while in the purulent discharge which arises later there are a large number of staphylococci and bacilli.

Etiology.—Acute eczema develops either as a primary affection or as part of an eczema of the face. It may arise without any known cause, or in consequence of external conditions, such as cold baths and douches, heat (eczema solare), warm fomentations, or the application of irritating remedies (chloroform, rancid fats and oils, mercurial ointments, mustard poultices, iodoform, etc.). One of the artificial forms of this disease is that circumscribed eczema which occurs on the superior surface of the crista helicis. It usually appears symmetrically on both ears and in persons who sleep on hard pillows. Occasionally it comes on as a sequela of seborrhœa and coincident with pediculosis capitis. Acute eczema very often arises in the course of an acute or chronic otorrhœa. This is brought about by the irritating secretion, and is especially observed in children and in those individuals whose skin is delicate and easily irritated. As a rule, individuals of a scrofulous dyscrasia and those affected with rickets are especially predisposed to eczema.

Symptoms.—The acute form begins with a feeling of heat, burning, and itching, which is followed by great pain after the appearance of the vesicles. In children, more rarely in adults, the disease is accompanied by slight pyrexia, restlessness, and sleeplessness.

The hearing is normal in those cases in which the eczema is limited to the auricle. If the auditory canal is affected, a mechanical disturbance of hearing, which is often combined with tinnitus, is brought about owing to the swelling of the lining membrane of the canal, and to the accumulation of desquamated epidermis, exudate, and crusts.

Course.—Acute eczema generally runs a typical course. In the milder forms of the disease, the vesicles quickly dry up on the second or third day, whereupon desquamation of the epidermis takes place, and recovery ensues. More frequently, however, after rupture of these vesicles, there is an abundant discharge of clear secretion, which abates after several days, and the exposed parts become covered with light or brownish-yellow crusts. Under normal circumstances, when the exudation has ceased, a new layer of epidermis forms beneath the crust, which, after the latter has been thrown off, soon assumes its natural appearance. Sometimes, however, the exudation of a clear or purulent fluid beneath the crust continues for several weeks until a new epidermic layer has formed. After a cure has taken place, the skin at the affected part remains hyperæmic for a long time.

Terminations.—Acute eczema generally ends in recovery. This often takes place in a few days, but not infrequently only after several weeks. It sometimes heals at different parts of the auricle or meatus, while a new eruption breaks out at others. Repeated relapses, brought about by a continuance of the cause, by general illness, or by an extensive eczema on other parts of the body, occasion deep tissue-changes in the cutis, and favour the transition of the acute into the chronic form.

On the border between the acute and chronic eczema of the external ear is that subacute form of eczema crustosum and impetiginosum which is very often met with in young children, and is associated with an extensive subacute eczema of the head and face, or is the sequel of pediculosis capitis. It affects the retro-auricular niche on the posterior surface of the auricle, and the depressions and concavities of the concha. This form of eczema is especially characterized by a profuse production of adherent crusts and scales, which are situated upon an intensely congested and inflamed base. The intense itching, the excessive feeling of heat, and the intolerable tension induce the children to rub and scratch the ear, whereby painful abrasions are produced on the posterior surface of the auricle, which not infrequently bleed very freely. On the other hand, the absorption of the pus confined under these adherent crusts frequently leads to an extensive dermatitis, which is accompanied by fever. This condition, furthermore, often induces inflammation and suppuration of the retro-auricular and cervical lymphatic glands. If the proper treatment is employed, it is almost always possible quickly to subdue this very painful affection, and to prevent its transition into the chronic form.

Chronic Eczema.—This affection is differentiated from the acute form by the deeper tissue-changes in the cutis. While in the acute eczema the inflammation is chiefly confined to the superficial layers of the cutis, in the chronic form we find a hypertrophy of the subcutaneous connective tissue. Such a condition leads to a thickening, enlargement, and rigidity of the auricle, causing it to protrude from the occiput, and to a narrowing of the cartilaginous meatus. The secretion and crust-formation are mainly confined to the depressions of the auricle, and to the posterior auricular groove; on the remaining parts of the auricle there is an abundant desquamation.

Chronic eczema of the auricle and external auditory canal most frequently appears in the crusty or scaly form; still, the two forms may be combined. The crusty form is characterized by the formation of large scabs, under which there is an exudation of serous or purulent fluid. On the whole, it presents, therefore, the same phenomena as the acute eczema in the stage of scab-formation.

The scaly form is distinguished by a hyperæmia and hypertrophy of the cutis, associated with a continuous desquamation. This affection is often associated with eczema of the scalp, and is only rarely confined to the auricle or external meatus. Squamous eczema may arise from the chronic, moist form; it more often occurs, however, as a scaly eczema, without any preceding serous exudation of the cutis. In the milder cases the desquamation is very slight, and is confined to a few depressions of the auricle or to the parts surrounding the external auditory orifice. In the more severe cases, however, the affection spreads not only over the auricle and its surrounding parts, but over the entire auditory canal and external surface of the membrana tympani. We also find that in these cases the auricle is enlarged owing to great infiltration of the cutis, and that the canal is narrowed. We furthermore meet with ragged, slightly secreting fissures of the skin, which are situated mainly in the depressions of the auricle, at its superior and posterior place of attachment, and at the superior periphery of the external auditory orifice; such fissures do not, as a rule, yield easily to treatment.

Symptoms.—A troublesome itching is the most constant symptom of chronic eczema. It causes the patient to scratch the meatus with hard bodies, thereby producing a painful, intercurrent inflammation of the canal. Subjective noises are induced either by the meatus becoming plugged with desquamated scales or by a consecutive hyperæmia in the middle ear and in the labyrinth. In like manner, disturbances of hearing may arise from a simultaneous swelling of the mucous membrane of the tympanic cavity and of the Eustachian tube, without any mechanical obstruction in the auditory canal.

Course and Termination.—These vary according to the severity of the affection. The milder forms, which are confined only to the ear, may recover spontaneously, or disappear after a short course of treatment; the severer forms rarely recede spontaneously, and are very obstinate to treatment. Even in those cases in which apparent recovery takes place, a relapse sooner or later ensues. Painful follicular inflammations of the external auditory canal are sometimes intercurrent.

A rare termination of chronic eczema, especially of the crusty form, is in a true elephantiasis of the auricle (pachydermia). Where there is a large increase of connective tissue in the layers of the skin, an extensive lymph stasis occurs in the network of the cutis, which gives it a peculiar soft, doughy feeling. Slight mechanical injuries are sufficient in these cases to cause the thickened skin to break open, and frequent relapses are thereby brought about.

Diagnosis.—This is made from the objective symptoms mentioned above. According to Auspitz, chronic eczema may be confounded only with a disease which is of rare occurrence, and that is seborrhœa of the external meatus. Such a mistake can be avoided if we take into consideration the absence of redness and infiltration of the skin in the latter affection.

Prognosis.—Only in the milder forms is the prognosis of chronic eczema favourable as regards the recurrence of exudation or desquamation. On the other hand, it is less favourable in the diffuse cases, complicated with eczema of the scalp or other parts of the body, or if combined with hypertrophy of the cutis.

Treatment.—In the treatment of eczema, we must take into consideration the cause of the disease, and the stage in which it is seen. Although cases of acute eczema often heal spontaneously, it is nevertheless important, in the acute stage, to avoid such injurious irritations, which keep up the exudation and prevent the formation of new epidermis. The patient must therefore be forbidden to wash the eczematous parts with water or to syringe the ear, and must furthermore be instructed to protect the inflamed and moistened parts of the skin, or those laid bare by the bursting of the vesicles, from the action of the air, by covering them with unguentum emolliens or vaseline. Moist surfaces on the auricle are best covered with some antiseptic powder; this method of treatment is especially applicable for eczema intertrigo, which frequently occurs behind the ears of children. Calomel is recommended by Rohrer as very efficacious in the acute as well as in the moist forms of chronic eczema. Powders, however, are unsuitable for acute eczema of the meatus, as the passage rapidly becomes obstructed. Eczema of children is also treated by a combined treatment of zinc oxide *plus* oil and Goulard's lotion. The sore, reddened parts are first carefully washed with small cotton pledgets dipped in Goulard's lotion; they are then dried, care being taken to avoid rubbing, and are covered with a thick layer of a salve made of zinc oxide and olive

oil in the proportion of 1 : 2. Dusting with powder is superfluous. This procedure is to be repeated at least three times a day. Cold applications of a solution of acetate of lead, or Burow's solution (diluted four times), or a 2 per cent. resorcin solution, are only indicated in the stage of vesication when there are extensive and painful eruptions. Ichthyol, which has lately been recommended, has also proved useful in many cases when applied in its crude form in an aqueous or alcoholic solution (1·0 : 50·0), or in the form of a salve (1 : 10). A salve of ung. hydrarg. præcip. ʒii. and ung. zinc. oxid. ad q.s. ʒi. has proved most beneficial in most forms of eczema.

A useful vehicle for the external application of ichthyol is filmogen (Schiff) The eczematous parts are pencilled three times a day with a 10 per cent. ichthyol-filmogen solution; this should not be done until a new layer of epidermis has formed, and until the inflammatory phenomena have disappeared. Filmogen forms a protective skin over the diseased parts.

If the patient is seen in the stage of scab-formation, the crusts must first be removed in order to facilitate the action of the remedies employed. The scabs are best softened by the free application of vaseline, cod-liver oil, sweet oil, balsam of Peru, or some soothing ointment, whereupon the softened masses may be easily removed on the following day with a brush or forceps. The application of Burow's solution in the above-mentioned strength is a most excellent remedy, because it possesses the peculiar property of quickly macerating and loosening even the most adherent crusts.

After removal of the crusts, and without further irritation to the exposed parts, the auricle and its depressions are anointed with a medicated salve. The following are the most serviceable: Hebra's diachylon ointment (prepared with olive-oil); unguentum vaselin. plumb. (empl. diachyl. c. vaselin., pur., ana part. æqual.); unguentum acidi borici (1 : 15 vaselin.); unguentum oxid. zinc. (1 : 30); Lassar's paste (zinc. oxid., amyli orizæ., ana 25·0, acidi salicylici 1·0, vaselin. 50·0); ung. hydrarg. præcip. ʒii. to ung. zinc. oxid. ʒi. In the external auditory canal, it is best to use small pledgets of cotton impregnated with the ointment. These, as well as the dressing on the auricle, must be changed every twenty-four hours; the ointment, mixed with the exudate, should not be washed off, but carefully removed with cotton dipped in oil, albolene, or liquid vaseline. Janovsky recommends the introduction of small mull pledgets covered with zinc ichthyol or zinc oxidthymol salve. Before their introduction the meatus should be pencilled with a 5 per cent. solution of silver nitrate. Salicylic soap plaster (acid. salic. 1 to empl. saponat. 10), introduced into dermatology by Pick, has also proved of value in the treatment of the crusty, impetiginous, and scaly forms of eczema. The same remark applies to the already mentioned Beiersdorff-Unna's mull salve (zinc, boracic, and salicylic acid), the skin

preparations recommended by Hebra, jun., and the medicated tragacantha gelatines, especially the combined zinc and boracic acid gelatine. The latter is used in a 5 to 10 per cent. mixture once or twice a day. The medicated gelatine, without previous warming, is applied to the diseased parts, where it hardens and forms a protective covering. Pencilling with a 1 to 3 per cent. solution of silver nitrate, as recommended by Wilde and Knapp in the scaly form of eczema, is useful only in obstinate cases.

After the crusts have been cast off, the newly-formed epidermis is tender, its power of resistance is lessened, and the cutis remains hyperæmic for a long time. All irritation, therefore, which might destroy the epithelium and increase the hyperæmia of the cutis, as frequent washing and rubbing of the skin, as well as syringing of the meatus, must be avoided. Hence, we confine ourselves for several weeks to the application of a thin layer of lanoline, vaseline, cold cream, or Lassar's paste to the affected parts.

The treatment of squamous eczema is regulated by the intensity of the desquamation and by the amount of infiltration of the skin. In the milder forms of eczema squamosa of the auricle, repeated paintings with tinctura rusci, carbolic alcohol (1 : 30), an alcoholic solution of boracic acid (1 : 20), or frequent cleansing with tar- or soft-soap (Auspitz), are sufficient to effect a cure. Unna recommends unguentum resorcin. compos. (resorcini, ichthyol, ana 5·0; acid. salicyl., 3·0; vaselini, 100·0); furthermore, tar-casein varnish to cover the crusts, or the pencilling with tumenol tincture (tumenoli, 5·0; æth. sulph., spirit. vini rectif., glycerin., ana 15·0). Ehrmann recommends a paste of anthrasol, which is better than tar, for the reason that it has no colour* (anthrasoli, 2·0; lanolini, vaselini, ana 15·0; amyli, oxidi zinci, ana 10·0). Also lanigallol, a triacetate of pyrogallol, which serves as the base of Lassar's paste, has often given good results in a 1 to 2 per cent. mixture in cases of dry eczema which are not too chronic. On the other hand, the severer forms associated with marked thickening of the epidermis and infiltration of the cutis prove very obstinate to treatment. If the epidermis is thickened and indurated, it must be softened by the daily application of a 10 to 15 per cent. salicylic soap plaster, or with fomentations of Burow's solution. Those parts which prove obstinate to the treatment must be thoroughly washed with tinctura saponis viridis, in order to remove the thickened epidermis. Applications of prepared pyrogallic or chrysarobin plasters have a good effect; these should be applied for two to three days, and only at night. The use of simple or salicylated gutta-percha plasters, as recommended by Unna, has proved very efficacious; these plasters, which adhere well and can be adapted to the form of the auricle,

* Anthrasol is made from tar by the removal of the resinous and colour material.

have a powerful macerating and softening effect. We are some-times able by this method alone to heal a chronic scaly eczema; at any rate, after this treatment has been used for one or two weeks, there is a marked diminution in the rigidity and in the tendency to cracking of the skin, and the fissures and clefts on the auricle are covered with new epidermis. If, after this time, the skin is not perfectly smooth, recourse may be had to treatment with the tar preparations. The manner of procedure consists in repeatedly painting the reddened parts with oleum rusci or cadini by means of a stiff brush, and then applying starch. If the skin becomes smoother, more flexible, and paler after the repeated application of the tar, we can resort to the following: Tar salve (oleum fagi, 10·0; glycerine, 5·0; unguentum emolliens, 40·0), painting with oleum cadini and glycerine (1 : 25), sulphur oint-ment (flor. sulph., oleum cadini, liquor styrac., ana 10·0; un-guentum diachyl. s. ol. amygdal., ana 15·0), resorcin ointment (1 : 10), pyrogallic ointment (1 : 10), chinosol paste (chinosol, 5·0; zinci oxid., amyli, ana 25·0; vaselini, 50·0), ichthyol ointment (1 : 10 lanoline), carbolic ointment (1 : 40), white or ' yellow precipitate ointment, and Wilson's ointment (resin benzoes pulv., 5·0; Axungia porci, 150·0; colat. adde oxid. zinci, 25·0). In the case of a dry, seborrhœic eczema, which is always accom-panied with hardness of the skin, resorcin sulphur ointment is often very serviceable (sulph. sublim., resorcini, ana 0·5 to 1·0; vaselin. flavi, 15·0). Sometimes the one, sometimes the other of these remedies proves effective.

For squamous eczema of the external auditory canal, painting the parts with a concentrated solution of silver nitrate has proved most effective to the author. After the scales have been removed from the walls of the meatus by means of a dry pledget of cotton, a 10 to 20 per cent. solution is applied with a brush or ball of absorbent cotton. The scabs fall off in a day or two in the form of brownish-black, dry scales, leaving the cutis smooth and pale. In the milder cases the cutis regains its normal appearance even after two or three applications. In the severer forms, combined with great narrowing of the cartilaginous meatus, the applications must be repeated more often (eight to ten times) in order to allay the swelling of the cutis. Veiel uses tar in the form of tar-spirit (1 : 10), to which some pyrogallol may be added (Leistikow). Fissures at the external auditory orifice are first treated with Lassar's paste or salicylic soap plaster, and only when these fail, with a 10 to 20 per cent. solution of silver nitrate.

In order to prevent relapses, it is necessary, after the caustic treatment, to anoint the cutis of the cartilaginous meatus twice a week with a thin layer of white precipitate ointment, or with a weak ointment of oleum cadini (1 : 40 vaseline), or with an ointment of flor. zinci, 2·0; resorcini, 0·5; anæsthesini, 1·0; vaselini,

lanolini, ana 15·0.   By this means the troublesome itching which often remains is most surely relieved.

When the eczema is cured, the accompanying disturbances of hearing and subjective noises often disappear.   This, however, is not always the case.

The internal treatment of eczema of the ear is often important, as a proper systemic treatment frequently has a most beneficial influence upon the course of the local lesion.   This is particularly true in anæmic and scrofulous individuals, especially in children, in whom the course of chronic eczema is often decidedly shortened by the internal administration of cod-liver oil, iron preparations, iodide of iron and arsenic (Fowler's solution, 3–10 drops daily, with a mixture of tincture of iron and malic acid).

Herpes zoster, lupus vulgaris, lupus erythematosus, pemphigus and psoriasis are some of the less frequent affections of the external ear.

D. Herpes Zoster.

This affection is characterized by the painful development of transparent vesicles which are arranged in groups, and situated on a highly reddened surface.   The site of the affection is either the posterior surface of the auricle, especially the lobule or the region in front of the tragus, and the anterior superior wall of the meatus. The situation depends on whether the herpes is caused by an affection of the trigeminus (anterior surface), of the great auricular (posterior surface), or of the ganglia belonging to these nerves.· Hartmann observed a case of herpes on the membrana tympani.   The formation of the vesicles is preceded by violent pains in the head and in the neighbourhood of the ear which seldom remit, and continue for several days.   After the appearance of the eruption, which is sometimes accompanied by fever, the pain generally subsides, but may continue until the vesicles dry up. Sometimes, as the author has

FIG. 97.—HERPES ZOSTER OF THE AURICLE IN A CHILD 9 YEARS OF AGE, AS OBSERVED BY DR. HERMET IN PARIS.

observed in a few cases, a facial paralysis develops on the affected side simultaneously with the eruption, which only disappears several weeks after the herpes has healed.   In one of the author's cases a neuralgia remained after the herpes, which disappeared several weeks after the eruption, was cured.

This affection ends in recovery. After the vesicles have burst, the diseased parts become covered with a crust, which falls off within a few days after the formation of a new epidermis. After cure has taken place, the affected parts remain hyperæmic for a long time. Owing to superficial gangrene, there is often a deep loss of substance, which heals by the formation of small cicatrices.

The treatment consists in combating the violent pain by the application of a 5 per cent. cocaine ointment, or a 10 per cent. orthoform or anæsthesin ointment, and by the internal administration of some sedative or narcotic. When these remedies prove ineffective, a subcutaneous injection of morphia may be given. The vesicles may be dried up by dusting them with powder, such as boracic acid, dermatol, or xeroform, or anointing them with unguentum plumbi acétatis or unguentum cerussæ.

Herpes zoster gangrenosus hystericus of the auricle is a rare form of disease. The author observed a marked case of this in a patient in whom the characteristic efflorescences of herpes zoster developed on the tragus and antitragus with the most excruciating pain. The base of the vesicles became necrotic in a short time, whereupon broad, obstinate ulcers, covered with a black scab, formed on the auricle. Healing took place with considerable cicatrization. The disease recurred three times in the course of a year, and finally led to a lasting deformity of the auricle.

E. LUPUS.

Lupus Vulgaris.—Lupus vulgaris of the auricle is sometimes observed as a part of an extensive lupus of the face. All known forms of lupus—lupus maculosus, exulcerans, hypertrophicus, papillaris, and framboësiodes—occur on the auricle. The character of the disease depends on the form of lupus with which the patient is affected on other parts of the body. Changes from one form to another occur here, just as in other portions of the body. As a rule we find disseminated patches of lupus maculosus on the lobule, in the concha, or on the posterior surface of the auricle. The patches appear in the form of brown, scaly tubercles varying in size from a pin's head to a lentil, which are grouped together, and penetrate deeply into the subcutaneous tissue. They seldom ulcerate, but may, nevertheless, through shrinking, produce cicatrices in the skin. From the small size of the efflorescences, the moderate formation of scales, and the characteristic shrinking with the formation of hard, often hypertrophied, keloid scars, lupus is differentiated from psoriasis. The latter affection occurs very seldom on the ear, and, as heretofore mentioned, only in connection with extensive psoriasis of other parts of the body.

Lupus Exulcerans.—Lupus exulcerans of the cheek sometimes attacks the anterior surface of the auricle, and gives rise to ulcers of variable size. These are covered with thick crusts,

after the removal of which the base presents a spongy, glandular appearance. The edges of the ulcers are often livid and undermined. It is often possible to find in the edge of the ulcer typical lupous nodules which are scattered in the cutis, and which have not yet ulcerated. The discovery of such nodules makes the diagnosis of lupus absolutely certain.

According to Neisser, lupus of the auricle assumes a very peculiar appearance when the lobule is simultaneously affected. In such cases it hangs from the auricle as a large, pear-shaped tumour, and ulcerates later than the other portions of the pinna. Up to the present, cases of lupus exulcerans limited to the auricle have rarely been seen. One case in the author's practice was that of a young man who was otherwise healthy, and who belonged to the better class; in this case the affection was limited to the auricle, and had existed for several months. The lupous ulceration first appeared on the upper half of the auricle, and extended from here to its posterior surface. On different parts of the anterior surface, the skin was so completely destroyed, that the cartilage, suffused with blood, was exposed. The sharply-defined edges of the ulcer appeared spongy and soft, and bled easily. By repeated applications of the sharp spoon, and cauterization with solid nitrate of silver, a cure was effected after some weeks, leaving, however, cicatrices and slight deformity of the auricle. In a second case (a girl twenty-five years of age), in which the lupous infiltration extended upwards from the inferior part of the lobule to the posterior edge of the auricle, a cure was effected after several months' energetic cauterization with solid silver nitrate without leaving any deformity.

Lupus Hypertrophicus.—Lupus hypertrophicus (tumidus, papillaris, framboésiodes) may come on as a primary affection, or it may develop on the floor of an ulcerating lupus vulgaris which has not been treated. While the lupous destruction of the skin progresses by the continued deposit of degenerating lupous nodules in the deeper parts of the cutis, there results a glandular and papillary growth of the excessively developed granulation tissue on the floor of the ulcer, which gives the auricle a deformed appearance. These granulations are often of a spongy, soft character, bleed easily, seldom become hard on their surface, and continue to suppurate at their base. These are the most malignant and obstinate forms of lupus, as they produce the most extensive destruction of the auricle. In cases which are specially protracted, the whole cartilage of the auricle may also become inflamed, infiltrated with pus, necrotic, and finally deformed by contraction. Such cases often go on to total destruction of one or more large portions of the auricle (lupus mutilans).

It is a very rare occurrence to see a lupus exulcerans, localized in the pharynx, extend through the tube into the middle and

internal ear. Gradenigo described such a case in which there
occurred a lupous destruction of the membrana tympani, ossicles,
mucous membrane of the cavum tympani, and vestibule. In a
case observed by the author of a man forty-three years of age,
the lupus exulcerans extended from the naso-pharynx towards
both tympanic cavities. In the first few months it appeared
as a chronic middle-ear suppuration, but later the lupous mass
extended through the perforated membrana tympani into the
meatus.

Treatment.—The treatment of lupus vulgaris of the auricle
consists (1) in the removal or destruction of the lupous granula-
tions, and (2) in guarding against deformities. In the ordinary
non-ulcerative form, these two objects are most easily attained
if we systematically destroy (by cauterization) only the true
infiltrate, and not the entire area in which the nodules are
situated. This is best accomplished by thoroughly cauterizing
the visible nodules with a pointed piece of lunar caustic, which
easily penetrates the soft, broken-down lupous tissue. This pro-
cedure is to be repeated until no nodules or spots are longer
visible. The consecutive cicatrization is relatively small by this
treatment, as the healthy skin between the spots of infiltration is
left intact. The same result as the above is obtained by cauter-
izing with potassium and silver, as introduced into practice by
Hebra. The method of procedure is as follows: Having thoroughly
cocainized the diseased parts, a 30 per cent. solution of caustic
potash is quickly applied, the result being that the affected areas
lose their superficial cuticular layer. The surface is now quickly
painted with a 25 per cent. solution of nitrate of silver, and the
superfluous fluid immediately sponged up by means of moist
cotton; the solution thus penetrates solely into the depth of
the lupous infiltration, which it destroys without injuring the
healthy tissue. For antiseptic reasons, it is recommended to
cover the wounded areas with iodoform gauze, or with dermatol
or xeroform. Lactic acid, which is highly recommended by
Mosetig-Moorhof, may also be employed in lupus of the auricle,
because it has a special destructive influence on the diseased
tissue, while it does not affect the healthy. Pencilling with
iodine glycerine (1 : 2) and concentrated carbolic acid are of less
value. Good results are obtained by using pyrogallic acid, which
is applied in the form of a 20 per cent. ointment several times
a day. Unna recommends the following salve: Acid. salicyl.,
liquor stibii chlorat., ana 2·0; creosoli, ext. cannabis indic.,
ana 4·0; adipis lanæ 8·0.

In all forms of lupus exulcerans, the ulcerating surface should
first be thoroughly cauterized in order to remove the granulation
tissue. Spongy and hypertrophied granulations must be removed
with a sharp spoon, after which the base of the ulcer should
be cauterized either with solid silver nitrate or with the galvano-

or thermo-cautery. By the continued use of these methods, it is always possible to destroy all the affected tissue, and to stay the progress of the disease; to achieve this, however, requires several months' treatment. Even if the contraction due to the formation of cicatricial tissue is considerable, and a marked deformity of the auricle remains after the lupus exulcerans has healed, still the thorough and energetic use of cauterizing agents is the only effective means by which not only healing is brought about, but the progressive deformity of the auricle is prevented.

Total excision of the lupous areas, with a subsequent plastic operation, has been suggested by Ed. Lang; this method of treat-

FIG. 98.—PLASTIC OPERATION IN A CASE OF LUPUS AS PERFORMED BY ED. LANG.

ment excels all others in regard to the certainty of success. When the lupus is confined to the upper and middle portions of the auricle, the diseased area, in conjunction with the cartilage, is excised in the form of a triangular wedge (Fig. 98), and the edges of the wound are united by an anterior and posterior skin suture. The auricle thereby becomes smaller without losing its form. If the inferior part of the auricle and the lobule are affected, the diseased part is excised and the removed area restored by means of a flap taken from the lateral region of the neck, the pedicle of which is behind the ear; by this procedure the contour of the auricle is brought back to its normal state.

A number of cases have been reported in which distinct improvement and cure were obtained by the recently recommended

treatment with hot air (Holländer), the Röntgen rays (E. Schiff and Freund), and photo-therapy (Finsen); whether the cures are permanent remains to be seen.   According to Ehrmann, it is advisable to combine the resorcin treatment with Röntgen or Finsen rays.   He applies to the diseased parts a 33 per cent. resorcin paste (resorcini 3·0, lanolini 4·0, unguent sp. 2·0) mornings and evenings.   Before each application he removes the white crust which has formed.   Every eight days there should be a pause of two days, during which time an ointment of boracic acid may be applied.   In the meantime, Röntgen or Finsen rays may be used.

Lupus Erythematosus.—This affection, which is really not a form of lupus, must still be mentioned.   It not infrequently appears localized on the auricle (lupus pernio), but generally occurs on its free edge and on its posterior surface with an extensive lupus erythematosus of the face.   It progresses without ulceration to cicatricial atrophy of the cutis.   In its acute, extensive form, known as erysipelas perstans, the auricle is always simultaneously affected.   The ordinary chronic form is treated with applications of soft soap, mercurial plasters (Wolf, Joseph), ichthyol collodion (Unna, Düring), painting with iodine glycerine (M. Richter), or by scarification followed by cauterization with chloride of zinc (Veiel).   Hebra, jun., recommends as beneficial alcohol applied as often as possible, or a mixture of alcohol, ether, and spiritus menthæ piperitæ in equal parts by means of cotton tampons.

F. Cutaneous Syphilis of the External Ear.

Primary syphilitic affections of the external ear are, on the whole, very rare.   Two cases of Hunterian chancre are cited in Lang's lectures on the *Pathology and Treatment of Syphilis*, p. 430 (Wiesbaden, 1885).   The one was reported by C. Pellizzari,[*] the other by J. Zucker.[†]   The location of the lesion was on the lobule in the one case, and on the anterior wall of the cartilaginous meatus in the other.   In both cases the cause of the affection was easily found.   In the first case, the infection was conveyed by a towel, which had been used by the syphilitic son of the patient; in the second case, infection took place from the too fervent caresses of a prostitute.   A third case of primary syphilitic infection of the auricle, reported by Hermet,[‡] occurred in a woman forty-two years of age, who acquired the chancre from her husband.   For the knowledge of a fourth case the author is indebted to the friendly communication of Dr. Hermet of Paris, who saw, at the clinic of Fournier, a phagedenic chancre on the lobule and on the posterior inferior third of the auricle.   The infection was acquired through a bite on the auricle, which the patient received during a fight with a syphilitic individual.

Secondary syphilitic affections of the auricle, in the form of macular, papular, and pustular eruptions, are always a part of a

[*] *Virch. Arch.*, vol. lxix., p. 313.
[†] *Zeitschr. f. Ohrenh.*, vol. xiii., p. 171.
[‡] *Annales de Dermatologie et de Syphilographie*, 2ème Série, Extrait.

general cutaneous syphilis, and especially when the skin of the forehead and scalp is simultaneously affected. Gummata are seldom met with in this region. According to Burnett, they may spread over the entire auricle, and may partially destroy it by the formation of deep-seated ulcers. In infants, broad condylomata occur on the inferior part of the auricle coincident with similar lesions on the adjoining parts of the neck.

Of the syphilitic lesions occurring in the meatus, condylomata and ulcers have been the most minutely observed.* Condylomata in the external auditory canal always develop with general syphilis, more often, however, if there are condylomata on other parts of the body. Their occurrence is usually simultaneous with the symptoms of general syphilis—*i.e.*, with the signs of syphilitic affections of the skin, pharyngeal ulcers, and sharply-defined, glandular swellings. Occasionally confluent condylomata occur in both auditory canals (Noquet, *Revue Mensuelle*, July, 1885).

The initial stage of condylomata, as a rule, escapes our attention on account of the absence of striking symptoms. According to Knapp (*Z. f. O.*, vol. viii.), they begin as red efflorescences, which gradually increase in size, and are followed by a diffuse swelling of the walls of the meatus combined with a moderate amount of secretion. These condylomata, in the form of red, or grayish-red, ragged, warty excrescences, arise more or less quickly on the secreting parts, and extend from the external auditory orifice to the osseous meatus, rendering the lumen of the auditory canal impermeable. In one of the author's cases, the condylomata were confined to the region of the cartilaginous meatus surrounding the external auditory orifice. In another case, they could be traced nearly to the tympanic membrane.

Although the initial stage runs its course without symptoms, violent, radiating pains, increased by movements of jaw, appear with the formation of the condylomata, especially if these have ulcerated; only in exceptional cases are these pains accompanied by fever. Subjective noises and deafness are caused either by a mechanical obstruction of the auditory canal or by a consecutive affection of the middle ear, which, as in a case observed by Knapp, may be associated with bilateral perforation of the membrana tympani.

Condylomata of the meatus heal either by resolution, or end in destruction with a discharge of profuse, fœtid secretion, and the

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* Among 1,200 syphilitic patients, of whom 980 had condylomata, Desprès (*Ann. d. mal. de l'or.*, etc., 1878) observed condylomata in the external meatus five times. Buck (*Am. Journ. of Otol.*, 1879), among 4,000 persons with ear disease, met with 30 cases of syphilis of the meatus, in 5 of which there were condylomata and ulcers. Ravogli (*Congressber. Mailand*, 1880), among 144 cases of syphilis, found the middle ear affected fifteen times, and the external meatus only once.

formation of unhealthy, confluent ulcers which are usually seated
on the inferior posterior wall, and are very resistant to treat-
ment. Resolution quickly follows an energetic general anti-
syphilitic treatment, and after the disappearance of the other
syphilitic symptoms. Cure, with or without cicatrization,
usually follows a rational, local, and constitutional treatment;
this may take place after several weeks, but is sometimes attained
only after several months. When no cicatrix is formed, that
portion of the meatus at which the lesion was located appears
somewhat sunken and devoid of hair. A stricture of the meatus
seldom remains as a sequela.

The diagnosis of condylomata can be made from the simul-
taneous existence of syphilis on the genitals, on the skin, and in
the pharynx, and from the accompanying glandular swellings;
if the examination is made in a perfunctory manner, the condy-
lomata may be taken for granulations. When ulcerations or areas
of infiltration occur on the external ear, or in the external meatus,
which arouse our suspicion that we are dealing with a syphilitic
condition, we must resort to a Wassermann examination of the
blood, in order to verify our diagnosis. The prognosis of condylo-
mata of the external auditory canal is favourable.

That a papular syphilitic infiltration may also occur on the external surface
of the membrana tympani is demonstrated by a case of Lang, who saw on the
drum membrane of a woman recently affected with syphilis a large, pale,
shining papule corresponding to the position of the processus brevis. In this
case the anterior superior quadrant was greatly injected and the whole mem-
brana tympani appeared opaque. Speech could be heard only at a distance
of five paces.

Gummatous ulcers of the external ear seldom occur without
a simultaneous affection of the cavum tympani. Alb. H. Buck
(*Am. Journ. of Otol.*, 1879) records several cases of syphilitic
ulcers on the auricle and in the meatus which had a charac-
teristic base and steep, elevated margins. That these lesions
were of a syphilitic nature was corroborated by the simultaneous
appearance of specific patches in the nose and pharynx, and by
the infiltration of the cervical glands. Hessler (*A. f. O.*, vol. xx.)
saw a partial necrosis of the auricle follow an ulcerating gumma.
Ravogli (*loc. cit.*) reported a case of nodular syphilis of the side
of the neck, in which several ulcerating, syphilitic nodules also
developed in the meatus and on the membrana tympani, and
which formed several isolated ulcers with a deep base and elevated
margins. Baratoux is supposed to have observed a gummatous
infiltration of the membrana tympani.

In a case which came under the author's notice, a characteristic
ulcer formed on the inferior wall of the meatus during the course
of a chronic middle-ear suppuration. The ulcer, which had a fatty
base, involved the inferior and lateral walls of the cartilaginous
meatus, and its steep, infiltrated margins were sharply demarcated

from the external auditory orifice.   The simultaneous occurrence of pharyngeal syphilis left no doubt as to the nature of the lesion.   In a second case, there was a round ulcer with elevated edges in the concha, in addition to one which occupied the whole length of the cartilaginous meatus.   Bruck saw a case in which there was a papular syphilide on the antihelix in addition to broad condylomata of the external auditory canal.

The treatment of condylomata of the auditory canal consists, besides a general anti-syphilitic treatment, in the repeated cauterization of the granulations with solid silver nitrate or a concentrated solution of chromic acid.   After the warty growths have diminished in size, they should be pencilled with a solution of corrosive sublimate (0·1 : 30·0) or with tincture of iodine. Knapp recommends dusting the condylomata with calomel, and later applying a 1 per cent. solution of nitrate of silver.

Diseases of the Perichondrium, Cartilage of the Auricle, and External Auditory Canal.

1. Othæmatoma (Hæmatoma auris).

Othæmatomata arise from a sudden effusion of blood between the cartilage and the perichondrium, by which the latter, with or without destruction of its continuity, is extensively separated from the former.   As the cartilage is traversed by numerous vascular bands of connective tissue, it is probable that an othæmatoma may be occasioned by rupture of these vessels through an act of violence; this condition may also be associated with partial tearing of the cartilage.

Etiology.—Othæmatomata are most frequently caused by injury, and seldom develop spontaneously.   The fact that the auricle often remains intact after a marked act of violence, while at other times a slight pull suffices to produce an effusion of blood, renders it probable that certain tissue changes in the cartilage, especially in aged, tubercular, and insane individuals, are the predisposing causes of othæmatomata.   L. Meyer, Pareidt, Haupt-Leubuscher, Simon, Virchow, Förster, and J. Pollak give the following as predisposing causes: Degeneration of the cartilage of the ear, softening and fissure formation, the formation of cavities with a gelatinous homogeneous contents, the proliferation of bloodvessels, and, finally, new growths.   It is probable that repeated injuries give rise to such changes in the cartilage, so that even the slightest violence may cause an effusion of blood.

Occurrence.—Othæmatomata may occur in healthy individuals, but they are seen most frequently, however, in those afflicted with diseases of the mind.   The left auricle is more often affected; the affection is seldom bilateral.   Gudden believes that they are solely caused by injury (ill-treatment), and finds that they are

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most common on the left side. Simon (*Berl. klin. Wochenschr.*, 1865), however, assumes that in lunatics they are always due to a tissue change in the auricle. Roosa (*loc. cit.*) connects the othæmatomata of the insane with a diseased condition of the brain. He bases this supposition on the experiment of Brown-Séquard, who observed hæmorrhages in the auricle after severing the restiform body of animals.

Symptoms.—Othæmatomata at first appear as bluish-red, rounded or irregular swellings, doughy or hard to the touch, and seldom present a distinct fluctuation. They occur more frequently on the anterior than on the posterior surface of the auricle. Those of spontaneous origin seldom attain the size of those due
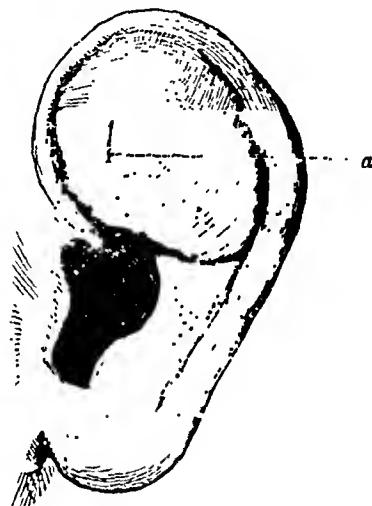
Fig. 99.—Spontaneous Othæmatoma on the Upper Portion of the Auricle, occurring in a Man aged 23.

Puncture of the painful tumour; perforation of the cartilage. Cure of the recurrent process was effected by means of repeated injections of a solution of nitrate of silver (2-4 in 10) after its existence for three months.

to injury. While the former occupy only small sections of the concave surface of the auricle, especially the concha and intercrural fossa, the latter appear as swellings which cover nearly the whole anterior surface, and sometimes occlude the external auditory canal. In transmitted light, that portion of the auricle in which the hæmorrhagic swelling is situated appears dark and non-transparent; this differentiates it from perichondritis.

Spontaneous othæmatomata often develop without subjective symptoms, while the traumatic are usually accompanied by great pain, heat, and tension. With the appearance of a reactive inflammation in the later stage of a spontaneous othæmatoma, severe pain is also experienced. Subjective noises and disturbances of hearing are observed only when the auditory meatus is

occluded by the swelling, or when the membrana tympani is injured simultaneously.

Course and Terminations.—The course of this affection depends on the extent of the hæmorrhage and on the simultaneous lesion of the cartilage. When the cartilage is not markedly altered by the hæmorrhage, the termination is far more favourable than when it is fissured by the extravasation. In a number of cases recovery takes place by resorption without malformation of the auricle, while in other cases the latter remains greatly deformed through cicatricial thickening, atrophy, and shrinking of the cartilage and skin, or through necrosis of the cartilage. In rare cases, more commonly in the traumatic than in the spontaneous forms, an extensive inflammation of the cartilage and its covering may develop, with a simultaneous hæmorrhagic, gelatinous exudate, which later becomes purulent or putrid. This may lead to partial suppuration, putrefaction, and multiple perforations of the cartilage and cutis, and may even end in partial loss of the auricle, or in a cicatricial deformity of the same, with a cleft-like narrowing of the meatus. Yasuraburo Sakaki[*] saw among seventy-two wrestlers twenty-nine cases of traumatic othæmatomata which terminated in connective-tissue and cartilaginous growths, and in shrinking of the auricle. On the other hand, Minca (Reports of the Medical Faculty in Tokio, vol. vi.) could not find even the forerunner of any proliferations in the cartilage, but only retrogressive metamorphoses in the form of hyaline degenerative areas. A fatal termination in consequence of pyæmia resulting from gangrene is a very rare occurrence.

Diagnosis.—The diagnosis of othæmatoma may be made with absolute certainty if it can be demonstrated that the swelling appeared shortly after an injury. In the spontaneous form the diagnosis is determined by the rapid development of the swelling. If we bear this in mind, it is impossible to mistake it for a perichondritis, an angioma, or a new growth.

Prognosis.—The prognosis of traumatic othæmatoma, in reference to absorption of the swelling and malformation of the auricle, is more favourable than that of the spontaneous form. This is true of all cases excepting those in which, through injury, a deep-seated change in the cartilage has taken place. A favourable symptom during the course of the affection is a diminution in the size of the swelling without any reactive phenomena. An unfavourable symptom is the appearance of violent inflammatory phenomena, which necessitates the opening of the infiltrated area.

Treatment.—When the swelling is small and painless, it is best to allow the process to pursue its own course, as all treatment, such as the application of a pressure bandage, massage,

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[*] Reports of the Medical Faculty in Tokio, *Ueber die Pankratiastenohren der japanischen Ringkämpfer*, 1899.

etc., rather tends to renew the bleeding and retard the absorption of the extravasation. For this reason, therefore, massage, recommended by Meyer (*A. f. O.,* vol. xvi.) and Blake (*Z. f. O.,* vol. xiii.), must be used with great caution, and by no means in the beginning, but only in the third or fourth week. When the swelling is painful, neither a pressure bandage nor massage must be employed. On the other hand, when the othæmatomata are of traumatic origin, or when they run their course with inflammatory symptoms, cold compresses, by means of ice-bags or Leiter's apparatus, are indicated; when the pain subsides, the treatment is continued with wet dressings of Burow's solution. When, in spite of antiphlogistics, the pain does not cease after four to five days, and the swelling has not decreased in size, cure is most rapidly effected by puncture and removal of the contents, followed by the application of a loose pressure bandage. In some cases the cavity refills with blood or viscid fluid, so that repeated punctures become necessary. When the tumour is of large size, R. Chimani recommends incision and packing with carbolic or salicylic cotton, or iodoform gauze.

Hæmorrhages into the external auditory canal are most frequently caused by injuries of the cutis or cartilage, and by fracture of the osseous walls. The inflammatory extravastions of blood were described in the chapter on Otitis Externa Hæmorrhagica.

2. Perichondritis of the Auricle (Perichondritis auriculæ).

Perichondritis of the auricle is of rather common occurrence. It develops without any known cause, or as the result of infection, and is confined to the anterior surface of the auricle without involving the lobule. This is the characteristic feature of this form of inflammation. The external auditory canal either remains intact or the inflammation begins there and extends to the auricle. It has been repeatedly observed to follow the radical mastoid operation for chronic suppurative otitis media, in which Körner's or Panse's plastic operation had been performed. In these cases, it is not the injury to the cartilage which causes the perichondritis, but infection due to the *Bacillus pyocyaneus* (Körner, Lermoyez, Neumann, Voss).

Symptoms.—When the inflammation has reached its climax, a red, or bluish-red, uneven, fluctuating swelling is found on the anterior surface of the auricle; it extends over the greater part of the concha and fossa of the helix, and appears sharply demarcated from the lobule below. The temperature of the affected part is raised during the first stage. When the affection first appears, it shows a great similarity to an othæmatoma, but is differentiated from the latter by its gradual development with inflammatory phenomena, and by the character of its contents,

which consists either of a synovial or purulent transparent fluid free from blood. After the tumour has existed for some time it becomes difficult to distinguish it from an othæmatoma, because, as we have seen, there are times, especially in its later stages, when the latter occasionally contains no blood, but only a transparent syrupy fluid. Probing the incised tumour reveals a more or less extensive loosening of the perichondrium, and exposure of the uneven, rough cartilage.

Terminations.—The terminations of perichondritis are: Recovery after spontaneous absorption of the exudate, or after the formation of an abscess and the discharge of the purulent, synovial fluid, without a change in the form of the auricle; or shrinking and marked deformity of the cartilage, as are observed in the severe forms of othæmatoma. The course of this affection is always protracted. Haug has reported a tubercular form of perichondritis. The duration of the inflammation varies from three weeks to three months.*

Treatment.—Treatment should be begun with the energetic application of antiphlogistics, and with early incision of the fluctuating mass. Burckhardt-Merian and Urban Pritchard saw rapid healing take place after puncture, followed by injections of dilute tincture of iodine. Many cases treated by the author in this manner resulted in a painful enlargement of the tumour, and recovery took place only after incision of the skin and the subsequent insertion of a tampon of iodoform gauze. The treatment with antiseptics, and with the pressure bandage, is the same as that already referred to in the treatment of othæmatoma. Kuhn recommends massage. Haug obtained a cure without deformity by repeated puncture and aspiration.

We must also mention those very rare affections, as gangrene of the auricle, met with in children (Politzer, Kruckenberg, Eitelberg, Nottingham), and noma of the auricle as described by Hutchinson (*Medical Times and Gazette*, 1881). The latter disease usually starts from the cartilaginous meatus. It is usually impossible to prevent a fatal termination in these cases even with the aid of radical surgical procedures. The cause of this disease is supposed to be an anaerobic form of streptothrix (Hoffmann, *Z. f. O.*, vol. li.). Max saw perforations of the auricle develop after grangrene. After removal of the necrosed parts, and cauterization with silver nitrate, cure was obtained. We must still mention pemphigus gangrenosus, an affection which is frequently met with in the lower classes of Ireland; it appears behind and on the ears, has a phagedenic character, and is generally fatal. Rohrer saw a case of simple pemphigus in which bullæ developed the size of hazel-nuts. V. Tröltsch, Brieger, and Politzer observed the bullæ of pemphigus in the auditory canal. Jarisch and Chiari described a case of tubercular ulcer of the auricle of a phthisical patient.

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* Wilde, *Prakt. Bemerkungen über Ohrenheilk.*, German translation, 1855; R. Chimani, *A. f. O.*, vol. ii.; H. Knapp, *Z. f. O.*, vol. x.; O. D. Pomeroy, Trans. of the American Otol. Soc., vol. ix.; Benni, *Baseler Kongress-bericht.*

Strictures and Adhesions of the External Auditory Canal.

Strictures of the External Auditory Canal.—These are caused by infiltration and swelling of its lining membrane and periosteum; by cicatricial contractions, hyperostoses and osseous new formations of its walls; and by other forms of new growth. Strictures caused by swelling and hypertrophy of the cutis are most frequently brought about by the secondary inflammations which arise during the course of a chronic middle-ear suppuration, by chronic eczema, and by the primary forms of otitis externa. Temporary strictures, caused by swelling and bulging of the posterior superior wall of the meatus, are observed in cases of acute mastoid abscess. They are also induced by a diphtheritic or syphilitic ulceration which has run its course, by injury and cauterization of the lining membrane (with concentrated acids, galvano-cautery, solid silver nitrate), by an unskilful suturing of a detached auricle (Bishop of Chicago), and by a faulty after-treatment in the radical mastoid operation. In old persons we occasionally find the external auditory orifice in a state of fissure-like contraction, owing to atrophy, shrinking and collapse of the cartilaginous meatus.

Strictures are either temporary or permanent. Swellings of the cutis, which are caused by acute or chronic inflammatory infiltration, and which often recede spontaneously or through proper treatment, may be reckoned to the former class. Sometimes, however, in an infiltration of the cutis of long standing, a new formation of connective tissue occurs with permanent thickening and condensation of the cutis and periosteum. This condition is associated with a considerable contraction of the lumen of the canal, and is especially met with in protracted cases of eczema, and during the course of a chronic suppuration of the middle ear.

Strictures caused by ulceration and cauterization present a different aspect. In some instances they are circumscribed and annular, and, as in the cases observed by Morpurgo and the author, resemble the diaphragm of an optical instrument; they may thus reduce the lumen of the canal to a size varying from that of a pin's head to that of a small lentil. This condition may easily be mistaken for perforation of the membrana tympani if we do not notice the short distance between the newly-formed membrane and the external auditory orifice. In other cases permanent, tortuous strictures are formed through extensive callous condensation and shrinking of the subcutaneous connective tissue and periosteum; these are generally located in the middle of the meatus, in its cartilaginous portion. The stricture in these cases is either circumscribed or diffuse; the former variety

usually affects the middle portion of the meatus, while the latter, as a rule, extends from the external auditory orifice into the osseous meatus.

Osseous strictures are caused either by a uniform periosteal growth of the walls of the meatus or by a hyperostosis which arises principally from the posterior superior wall of the osseous meatus where it sinks like an inclined plane from without inwards towards the inferior wall of the canal, and, by causing a cleft-like narrowing, obstructs the view of the membrana tympani. Such strictures, which are usually associated with a high degree of deafness, often develop after the recession of a carious process of the temporal bone, especially after the exfoliation of large sequestra from the mastoid process through an opening in the wall of the meatus. The slit-like contraction of the external auditory canal, formed by the abnormal inward curvature of its anterior inferior wall, is due in the majority of cases to an anomaly of formation.

Strictures of the external auditory canal are either round or slit-like, and occasionally present the form of an hour-glass. After a suppuration of the middle ear has run its course, the constricted part of the meatus generally remains unchanged.

Strictures of the external meatus, even when marked, occasion a disturbance of hearing only when they are accompanied by pathological changes in the middle ear, or by the accumulation of thickened secretion behind the stricture. If, on the other hand, the external meatus is entirely occluded by the stricture, the disturbance in hearing may be very marked, and may even lead to complete deafness. This is especially true if the stricture is of a bony nature. Where a chronic suppuration of the middle ear exists, the discharge of the pus may be hindered by the stricture, so that a fatal complication may be induced.

In the examination of strictures, the use of the probe is indispensable. By this means we are in a position, not only to distinguish a membranous from a bony stricture, but to judge its extent and calibre.

Treatment.—This depends on the anatomical cause of the contraction, and on the condition of the middle ear, and the parts of the external meatus lying behind the stricture. In contractions caused by swelling and hypertrophy of the cutis. it is advisable to gradually dilate the parts by the insertion of conical, resistant plugs of charpie; these plugs should be of graduated sizes. This procedure should be adopted only when the swelling and hypertrophy cannot be relieved by the treatment described under diffuse inflammations of the external auditory canal. Should these plugs prove ineffective, compressed sponge-tents, which have been sterilized or previously soaked in iodoform ether (10 per cent.), should be introduced into the

meatus and allowed to remain until they swell up, causing a moderate pain. Laminaria-tents of increasing size are sometimes employed for this purpose. A too energetic attempt at dilatation may bring about a subsequent adhesion of the walls of the meatus if the epidermis is torn off by the pressure of the dilating body, and the exposed parts come into contact with each other. Rapid dilatation with sponge or laminaria tents, and the later introduction of small thin rubber tubes, are indicated only when it is necessary quickly to remove stagnant secretion from the deeper portions of the meatus and from the tympanic cavity; such a radical procedure is undertaken to avoid serious complications which may be occasioned by the retained secretion. By inserting a tympanic tube 10 cm. long into the deeper parts of the meatus and injecting warm water, the secretion is most readily removed. When the external auditory orifice is reduced to a slit-like aperture, as a result of atrophic shrinking and collapse, it is recommended to introduce a small, well-fitting, resistant rubber tube, or a silver cannula.

Strictures of long standing, caused by hypertrophy of the lining membrane of the auditory meatus, generally prove very obstinate to the methods of dilatation mentioned above, inasmuch as, even after the repeated application of sponge-tents or laminaria, the contraction again returns to its former state. Sometimes, moreover, an inflammatory condition is occasioned by the mechanical irritation, and thus the stricture may even be increased. In such cases, as well as in strictures due to cica-

Fig. 100.

trices, repeated longitudinal scarifications of the meatus followed by the introduction of compressed sponge-tents, and the long-continued wearing of conical vulcanite cannulas (Fig. 100), have proved of great service. A considerable dilatation was accomplished in a number of cases by the continued wearing of such small cannulas; by using four or five of these tubes of progressive size a gradual dilatation is brought about. The length of the tube varies according to the depth of the stricture in the canal. Diaphragmatic septa may be permanently removed by circular incision, or by the galvano-cautery. Ostmann succeeded in removing connective-tissue strictures by electrolysis in four sittings, each lasting five minutes. Jansen recommends excision of the callous and cicatricial tissue after the auricle and posterior wall of the cartilaginous meatus have been detached; he replaces the defect by a pedunculated flap taken from the cutis of the mastoid process. Long osseous strictures, accompanying chronic suppuration of the middle ear, are sometimes an indication for the opening up of the middle-ear spaces, and a simultaneous removal of the posterior and superior walls of the canal, especially
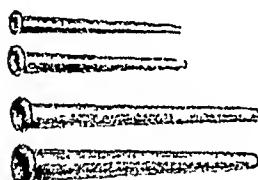
if symptoms of pus retention become manifest. Strictures are furthermore caused by—

Exostoses in the External Auditory Canal.—According to Hedinger, exostoses of the meatus are the result of a hypertrophic inflammation of the lining membrane, with a subsequent osseous metamorphosis of the new-formed connective tissue. J. P. Cassells (Med. Congr., London, 1881) differentiates a hyperostosis and an exostosis; the former he considers a hyperplasia, the latter a new growth. There is no sharp line between these two forms; still, the term ' hyperostoses ' should be applied more to the diffuse bony growths which occupy the entire length of the meatus, and ' exostoses ' to the circumscribed, tumour-like, osseous new formations (v. Tröltsch). The structure of exostoses is either compact, spongy, or pneumatic. In a pedunculated exostosis operated upon by the author, the histological examination showed here and there very compact lamellæ (eburnation) with spaces that contained but few vessels.

Etiology.—The etiology of exostoses is obscure, in the majority of cases, because they frequently develop without inflammatory phenomena, and we are seldom in a position to observe their growth clinically. In a number of cases their origin can be attributed to the following causes: (1) Partial hyperplasia during the stages of development and ossification of the osseous meatus. According to the author's view, those bilateral, osseous neoplasms which develop without symptoms belong to this class, especially if they are located symmetrically in both meatuses and also have a corresponding form. They are found in the middle and inner sections of the osseous meatus. They are sessile or pedunculated, and seldom attain such a size that they completely block the auditory canal. (2) A chronic circumscribed periostitis of the osseous meatus. To this class we must reckon the round exostoses (osteophytes) which were described by Wagenhäuser, and which arise from fracture of the anterior wall of the meatus. (3) Primary, or circumscribed and diffuse, inflammations of the meatus, which develop during the course of a chronic middle-ear suppuration. To this class belong those exostoses which arise after the cessation of a chronic middle-ear suppuration, and which are occasioned by the ossification of cartilaginous new growths and polypi (Dalby). (4) Hereditary predisposition (Schwartze). (5) Syphilis (Roosa) and gout (Toynbee) are less frequently the causes of exostoses than was formerly supposed. That they are due to these diseases may be assumed only when osseous tumours occur simultaneously on other parts of the body, the origin of which can be traced to the general systemic affection.

Moos reported (*A. f. A. u. O.*, vol. ii.) three cases of symmetrical, bilateral exostoses on the superior wall of the auditory canal; in these cases a white nodule, larger than a hemp-seed, was situated on both sides of Shrapnell's

membrane. The author saw quite a number of such cases in his practice (Fig. 101), and was undecided whether he was dealing with a connective-tissue or osseous new growth.

Symptoms.—Exostoses of the external meatus appear as white or yellow tumours of varying size, and are usually smooth, seldom rugged: Their base is either broad and ill-defined, or distinctly circumscribed and constricted. They may arise from any part of the auditory canal, but generally take their origin at the union of the osseous with the cartilaginous meatus, and from the posterior wall of the osseous portion of the auditory canal, especially its external part, which is covered by the cartilagino-membranous portion. Those bony growths which develop here are often seen with the naked eye immediately behind the external auditory orifice. They usually attain such a size that they reduce the lumen of the auditory canal to a narrow slit. Through pressure of the new growth on the cartilaginous wall, the latter atrophies until it disappears entirely, or the exostosis becomes so intimately united with the cartilage that the tumour, when

FIG. 101.

FIG. 102.—PEDUNCULATED EXOSTOSIS REMOVED WITH A CHISEL FROM THE LOWER WALL OF THE MEATUS.

removed, may be mistaken for an ossified enchondroma. Noltenius described a specimen in which an exostosis, the size of a pea, completely blocked the external orifice of the osseous meatus, and arose from the anterior inferior margin of the pars tympanica by means of a small pedicle. In a case which the author had occasion to observe during life and at the *post-mortem*, the exostosis occluded the external auditory orifice, and proved to be a bony growth springing from the posterior part of the external opening of the osseous meatus; behind this tumour the auditory canal was enormously widened owing to absorption of its posterior wall.

One or more exostoses may occur in the auditory canal. Not infrequently two exostoses are found which narrow the lumen of the canal to a fissure or to the shape of an hour-glass, so that the membrana tympani is either completely hidden from view or only a small portion of it may be seen.* At times a small

* Cp. Politzer, *Atlas der Beleuchtungsbilder des Trommelfells*, Plate I., Figs. 9-12.

exostosis is situated upon a larger one. Bilateral exostoses are rather frequent, but their position in the meatus, however, is not always symmetrical. Ayres saw symmetrical exostoses in the meatus resembling a septum. The author once saw two bony growths in the left and three in the right osseous meatus; these arose from the anterior superior and posterior walls. The most frequent changes in the ear appearing simultaneously with exostoses of the meatus are: Chronic catarrh of the middle ear without any evident relation to the osteoma; chronic suppuration of the middle ear, with or without the formation of polypi in the meatus; chronic otitis externa, with a moderate desquamative secretion; and, finally, chronic eczema. As a rule, examinations made at intervals of several years show a stationary condition of the exostosis. In rare instances—and then only in suppurative processes—the bony growth increases rapidly in size. Those cases of spontaneous absorption of exostoses which are recorded in literature were most likely unorganized periosteal exudates.

The subjective symptoms accompanying exostoses of the auditory canal are more often caused by a simultaneous affection of the middle ear and meatus than by the tumour itself. Small growths of this nature which do not occlude the canal almost always run their course without symptoms. Large growths, on the other hand, may occasion an ulceration of the cutis, or a painful inflammation with suppuration by pressure against the opposite wall of the meatus; such an inflammation also attacks the bony growth itself. Moos observed a case in which a trigeminal neuralgia was produced by an exostosis, after the removal of which the nerve affection completely disappeared. A reflex cough occasionally occurs.

Apart from the deafness which exostoses may occasion through occlusion of the meatus, they also facilitate the accumulation of cerumen and epidermic masses in the deeper parts of the canal. Where exostoses in the meatus are associated with a suppuration of the middle ear, serious complications may arise from retention of the secretion, which may necessitate the opening up of the middle-ear spaces (mastoid operation).

Diagnosis.—The diagnosis of exostoses presents no difficulty to one of experience. Only when the lining membrane of the meatus is inflamed and swollen can the red swelling, covered with granulations and secretion, be mistaken for the bulging cutis or for a polypus. The resistance of the bony hard tumour, which is generally sensitive on being probed, leaves no doubt as to its nature.

Treatment.—When exostoses are of such a size that they completely fill the lumen of the auditory canal, and are associated with a high degree of deafness, we should first make attempts at dilatation, provided the middle ear and labyrinth are intact. If we can succeed in producing a small slit in the

lumen of the auditory canal through pressure on the exostoses by the long-continued wearing of a hard body between the growth and wall of the meatus, it will be found that this is quite sufficient for the entrance of the waves of sound. Bonnafont (*Union méd.*, 1863) describes three cases of marked deafness resulting from exostoses in the meatus; after the long-continued wearing of a small metal rod between the growth and the walls of the meatus, a small slit-like opening was produced, whereby the normal hearing function was re-established. V. Tröltsch saw an exostosis diminish in size through the wearing of laminaria tents for many years. In a case in which a retained piece of laminaria tent produced a superficial necrosis of the walls of the auditory canal, a considerable dilatation of the meatus and return of the hearing were evident after the removal of a small sequestrum.

It is seldom possible to remove the ceruminous and epidermic masses which have accumulated behind the exostosis by the ordinary methods of syringing, as the stream of water cannot enter the meatus with sufficient force through the slit-like opening. In such cases it is recommended to insert the point of a small tympanic catheter (*vide* p. 125) through the opening into the deeper parts of the meatus, and then to inject 10 drops of a warm solution of soda and glycerine by means of a Pravaz syringe, the nozzle of which fits into the outer end of the catheter. The masses thus softened are easily syringed out on the following day by a forcible injection through the catheter. If we are dealing with secretions due to inflammation, we must wash out the meatus by repeated syringing, and then instil alcohol or an alcoholic solution of boracic acid (1 : 20); if there are granulations, they should be removed.

The operative removal of exostoses is indicated (1) in marked deafness due to complete closure of the meatus, providing the tuning-fork tests show a normal condition of the labyrinth and no nerve deafness, and where there is a simultaneous disturbance of hearing in the other ear; (2) in inflammations of the external auditory canal, when the discharge of the secretion is prevented by the bony growth. The radical mastoid operation is indicated in cases in which the exostosis is complicated with a chronic middle-ear suppuration showing signs of pus retention.

The removal of exostoses by means of the gouge and hammer is superior to all other operative methods, and should be performed under a general anæsthesia. This procedure has the advantage of quickly removing the new formation. It requires great caution, however, in the case of deeply seated growths, as there is a possibility of injuring the deeper parts of the meatus. Removal with the chisel is especially suitable for pedunculated growths, as they can be detached from their base by two or three slight blows of the hammer. In a number of cases operated upon by the author, cicatrization took place within a few days.

In exostoses with broad bases, however, a long-continued suppuration has been known to occur after their removal. Where the exostosis is deeply seated, it is more advisable to detach the auricle and cartilaginous meatus first, and then to chisel away the bony growth. At the same time, a large part of the posterior and superior walls of the osseous meatus should be removed, and, out of the membranous portion, a flap should be formed which is tamponed against the posterior superior wall of the meatus. The retro-auricular wound is sutured, and with proper antiseptic precautions heals by primary union.

Destruction of the osseous tumour by means of the galvano-cautery, as recommended by Voltolini and Delstanche, can be used only in those cases in which the growth is situated in the external portion of the meatus. This method requires a long time to bring about a cure, but possesses the advantage of giving rise only to a slight hæmorrhage and moderate pain. Moos brought about a cure by the combined treatment with the galvano-cautery and laminaria tents. The elastic ligature of v. Dittel can be recommended for the removal of pedunculated tumours with a contracted base in those individuals who fear an operation.

The internal administration of the iodides and mercurial preparations and the intravenous injection of salvarsan are indicated only if we have cause to believe that the affection is due to syphilis.

Atresia of the External Auditory Canal.—Acquired atresia of the external auditory canal is caused—

1. By immediate contact of the walls of the meatus, which have been deprived of their epidermis during the course of a secondary inflammation of the canal, the latter being due to a chronic suppuration of the middle ear.

2. By combined caries and necrosis of the mastoid process and walls of the meatus; after the throwing off of one or more sequestra, the granulation tissue which has grown into the meatus becomes attached to the bony walls and changes into fibrous connective or osseous tissue. In such cases we not infrequently find, in addition to a bony atresia, retracted osseous cicatrices on the mastoid process.

3. By the coalescence of large granulations which arise from the walls of the osseous and cartilaginous meatus and completely fill its lumen, and which are deprived of their epithelium owing to continued contact. In these cases we also find that the connective tissue which occludes the canal becomes changed into a fibrous mass or osseous tissue.

In a case of chronic otitis externa which had run its course, and which the author observed during the life of the patient and at the *post-mortem*, the osseous meatus was filled with a cystic, pigmented connective-tissue mass. This mass had grown to the walls of the meatus and to the external surface of the membrana tympani, and left a fissure which extended along the posterior wall to the membrana tympani.

In a second case of chronic middle-ear suppuration, combined with facial paralysis, in which a pedunculated polypus extended to the external auditory orifice, the author found, at a later examination, an atresia of the meatus

caused by a complete adhesion of the growth with the walls of the canal. When the patient was first examined he refused operative removal of the polypus.

The autopsy of this very rare case showed a mass of connective tissue which entirely filled the external meatus and superior tympanic cavity, and extended into the vestibule, facial canal, internal auditory meatus, and into the cranium. Several connective-tissue growths, varying from the size of a pea to a hazel-nut, were found beneath the dura in the posterior cranial fossa, which were not only connected with each other, but also with the mass of connective tissue coming from the internal meatus.*

4. By traumatic lesions; by injuries from blows on the ear; from gunshot wounds, and poorly-united fractures of the external meatus; also by cauterizations, burns and ulcerations of the walls of the auditory canal. In these cases, the atresia is brought about either by contact of the denuded surfaces of the walls, or by the apposition of the granulations springing from the floor of the ulcer.

5. By an operation on the mastoid process which is incorrectly carried out, especially by a poorly-performed radical operation. In these cases the membranous portion of the external canal is freed from the osseous part, and if not properly treated causes a stricture or atresia of the entire canal. After a radical mastoid operation, if a plastic operation has not been performed, or poorly carried out, the external canal will become occluded and almost entirely closed.

6. By a phlegmonous, peri-auricular inflammation extending into the auditory canal, with the formation of an adhesive connective-tissue mass in the cartilaginous meatus.

A connective-tissue atresia is caused either by a membranous septum stretched across the external auditory orifice or osseous meatus, or by a long mass of connective tissue varying in thickness. A bony atresia, which is usually of considerable thickness, is most frequently situated at the internal part of the osseous meatus; it is rare to find such a bony mass blocking the entire canal.

The objective symptoms of atresia vary according to its position and extent. In the connective-tissue, as well as in the osseous forms of atresia, the walls of the meatus gradually pass into the growth—*i.e.*, without any sharp line of demarcation. This causes the meatus to appear as a pale gray or grayish-red glistening cul-de-sac. The further the atresia extends externally, the shorter appears the auditory canal. This fact is of importance in the diagnosis of this affection. Only when the atresia is located at the innermost part of the osseous meatus can the surface of the growth be mistaken for the membrana tympani. In such cases, the following points suffice to establish the diagnosis: the ill-defined margins of the growth, the absence of the short process

* A. Politzer, *Anatom. und klin. Studien über die erworbene Atresie des äusseren Gehörgangs. Wien. med. Wochenschrift,* 1890.

and handle of the malleus, and the shorter distance between the deeper parts and the external auditory orifice as compared to the other side.

It is necessary to carefully probe the atresia in order to ascertain whether we are dealing with a membranous, connective-tissue or osseous growth. Should the latter be the case, the parts feel as hard as bone. It is more difficult to differentiate between a membranous septum and a diffuse connective-tissue growth, especially if the membrane is somewhat thick and resistant. In such cases, examination with Siegle's speculum helps us in arriving at a correct diagnosis, as we are thereby able to detect distinct excursions of the central and thinnest portion of the septum, if it is of a membranous character.

The thickness of the atresia is sometimes ascertained through the hearing tests. In an osseous or extensive connective-tissue atresia, we usually find absolute deafness or a disturbance of hearing of a high degree, which is often accompanied by marked tinnitus. On the other hand, in a membranous atresia (septum formation) the hearing distance for speech may be almost normal. As the power of understanding loud speech is partly transmitted through the cranial bones, it is necessary when testing to employ a hearing-trumpet. It will generally be noticed in an osseous or extensive connective-tissue atresia that the words spoken through the trumpet will either be understood with difficulty or not at all. On the other hand, in those cases in which there is a rather thin membranous atresia, even soft, low speech can be well understood, providing the middle ear and labyrinth have not undergone any great changes. In those cases, therefore, in which whispered speech is understood through the hearing-trumpet, it is quite probable that the septum is very thin. In such cases we would, without any hesitation, resort to the operative removal of the atresia. In those patients, however, where speech is not understood with the aid of the hearing-trumpet—in other words, where we are dealing with an extensive atresia—the operative procedure of cutting through the same and introducing cannulas, as well as leaden plugs, is generally unsuccessful.

In a girl twelve years of age who, in her second year, developed a left, and in her fourth year a right-sided otorrhœa, and in whom the discharge ceased at the age of nine, examination showed a symmetrical cul-de-sac closure of both auditory canals, which was located almost in the middle of the osseous section (compare diagrammatic sketch of the right meatus in Fig. 103). The deeper parts were yellowish-white, which, on being probed, were somewhat resistant. The hearing distance, right and left, for the acoumeter was 1 cm., for loud speech 15 cm.; whispered speech, through the hearing-trumpet, was very well heard in both ears.

Encouraged by the results of these tests, the author divided the septum with a paracentesis knife. In the right ear a considerable improvement in the hearing immediately followed, and the patient was able to hear the acoumeter at 8 cm., and speech at 5 m. In the left ear, however, the septum proved to be disproportionately thicker and more resistant, and the improvement in the

hearing was comparatively slighter. After the operation, to prevent the repeated growth of the atresia, leaden plugs* were introduced and allowed to remain almost continually for several weeks. The following result was obtained: On the right side the opening remained persistent through epidermization of the edges of the septum, and a permanent improvement in the hearing ensued; on the left side, a slight reaction took place at the seat of operation, and, at a later date, the meatus again became occluded. The author has obtained similar good results in a number of cases in which he used the galvano-cautery to perforate a connective-tissue atresia.

A connective-tissue atresia, which takes in a larger part of the meatus, can be removed successfully only by operative means, provided that the connective-tissue mass, which fills the meatus, does not extend into the tympanic cavity. Therefore an operative measure should be decided upon only when, by the aid of the tuning fork tests, the auditory nerve is found to be intact; and when, by means of auscultation, air can be heard to enter the tympanic cavity during catheterization. The same also applies to an osseous atresia of the meatus.

FIG. 103.

a, Cartilaginous meatus; b, Septum in the osseous section; c, d, Peripheral thickened part of the septum.

In the case of a peasant boy operated on by the author at his clinic, the cheek and auditory canal were severed in consequence of a cut from a sabre on the right side of the face; the injury healed by the formation of an atresia which extended from the external auditory orifice to the osseous meatus. In spite of the above, whispered speech was heard at several metres from the ear. The operation consisted in the detachment of the auricle from its posterior insertion; the imperforate cartilagino-membranous meatus was then severed from its attachment with the osseous portion, whereupon it was lifted out and cut off at the external auditory orifice. The membrana tympani was perforated and covered with pus. In order to produce an auditory canal of sufficient width, a part of the posterior osseous wall was chiselled away, and to this bony surface two pedunculated flaps taken from the skin of the mastoid process were transplanted. The anterior, inferior, and superior walls of the meatus were covered with Thiersch's skin-flaps taken from the leg, and after widening the external auditory orifice by means of two incisions into the concha, there was produced an auditory canal which remained permanently wide, and which was covered with epidermis. In spite of the perforation in the drum, the hearing distance for conversation speech was 6 m.

In a second case, a man in the thirties, an osseous atresia near the external auditory orifice developed from a chronic suppuration of the middle ear; it could be demonstrated that the atresia was not thick, inasmuch as the sound produced by air entering the tympanic cavity could be heard through the imperforate part during catheterization of the Eustachian tube. After the osseous atresia was chiselled away, the inner part of the osseous meatus was found to be normal in width, a perforation was present in the membrana tympani, and the mucous membrane of the tympanic cavity was pale and dry. The surface of the wound was covered over by epidermis which sprang from the cutis of the cartilaginous meatus. The hearing distance for speech, which was $\frac{1}{4}$ metre before the operation, increased to $3\frac{1}{2}$ metres.

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* The introduction of correspondingly strong leaden tubes is preferable to that of leaden pegs, as the wearing of the former interferes but slightly with the power of hearing.
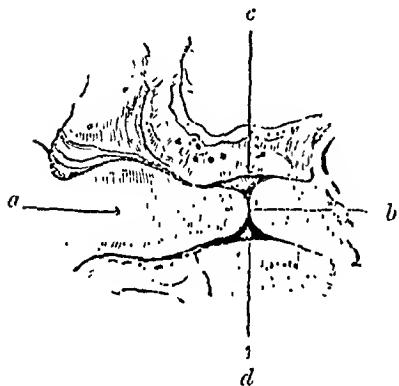
Foreign Bodies in the Ear.

Foreign bodies in the meatus are most frequently seen in children, who insert various articles as peas, beans, pieces of paper, cherry-stones, coffee-beans, carob-stones, pebbles, glass beads, wooden balls, fruit-stones, sealing-wax, slate pencils, metallic buttons, shot, and so forth, into their ears. In the case of adults, the entrance of a foreign body into the meatus is generally accidental. According to the author's observations, pieces of camphor and garlic are more frequently met with than any other foreign bodies in the ear. This is explained by the fact that they are often introduced by the laity to relieve the pain of tooth- and ear-ache. Other foreign bodies found in the external canal are those used for scratching the walls of the auditory canal; among such one finds the bone or porcelain heads of small lead pencils, rolls of paper, toothpicks, matches, and earpicks. Besides these, pellets of cotton, leaves, small branches and roots, as well as grains of wheat, millet, barley, and oats, are also often found.

Symptoms.—The symptoms produced by foreign bodies are usually very slight, or entirely absent; indeed, experience has shown that the ill-effects which arise are due (with but few exceptions) to the unskilful attempts at extraction by the inexperienced practitioner.

In a considerable number of patients examined for other disorders of hearing, the author found the greatest variety of articles in the auditory canal, of which the patient had not the slightest idea, and which must have been in the meatus for some time. The author once found the piece of a slate pencil, 3 cm. long, in the ear of a patient who was seventy years of age, which, according to his own statement, had been in the meatus for fifty years. As the patient experienced no discomfort, he allowed it to remain until deafness, caused by a ceruminous plug, induced him to seek medical advice. In one of the author's students he removed a piece of lead pencil 1 cm. long, which had been in the ear twenty-two years. In this case the patient believed that the foreign body had fallen out soon after it had been inserted. Brown found in both meatuses of a boy several pebbles which had remained there for seven years. In a case reported by Lucae, a cherry-stone had been in the ear for forty years, and in a case of Zaufal's for forty-two years. Reim removed a molar tooth which had been in the ear for forty years, Maschal a coral rosary bead which had been in the meatus for forty-five years, and Marian a glass pearl from the ear of a peasant which had been there since childhood. Bacon, Pritchard, Gomperz, and others, have recorded similar cases in which foreign bodies have remained in the ear for many years.

Sometimes foreign bodies cause not only violent reflex phenomena due to irritation of the trigeminus and vagus nerves, but also persistent, general nervous attacks, which disappear only after removal of the foreign body.

The literature on diseases of the ear abounds with cases of this nature, a few of the most interesting of which the author will mention here. Fabricius v. Hilden* cured a girl suffering

* Politzer, *Geschichte der Ohrenheilk.*, vol. i., p. 153.

from epilepsy, dry cough, hemianæsthesia and atrophy of the left arm by the removal of a glass bead which had remained in the meatus eight years. According to Frey and Fuchs (*Arbeiten aus dem Neurologischen Institut in Wien*, vol. xiii.), epileptic attacks are induced in children and in predisposed individuals by foreign bodies in the ear and nose. Arnold (cited by Moos) found that two beans in the ear of a girl were the cause of a persistent cough associated with frequent vomiting; after removal of these bodies the symptoms vanished, and she was absolutely cured. In a case reported by Toynbee (*loc. cit.*) an obstinate cough ceased after the removal of a sequestrum.

As a rule, the ill-effects of foreign bodies are produced by irrational and forcible attempts at extraction. As a result the meatus, and sometimes the membrana tympani, are not only injured, but the body, which is generally situated in the carti-laginous section, is driven into the osseous meatus, and is either impacted in the narrowest part of the latter or, after rupture of the membrana tympani, is forced into the middle ear.

Through such manipulations, which are usually combined with marked hæmorrhage, a painful traumatic otitis externa, and some-times a suppurative inflammation of the middle ear, are pro-duced. As a result of this, the meatus becomes so narrowed through swelling and the formation of granulations that the foreign body is hidden from view, and its removal is either rendered very difficult or quite impossible.

In the course of such inflammations, the swelling in the meatus may either recede spontaneously or through proper treatment, thereby facilitating the operative removal of the foreign body. Very often, however, the inflammation and suppuration are kept up so long by the retained body that it is either discharged spon-taneously with the pus or is easily extracted. Where the lesion and inflammation are confined to the external meatus, a cure generally follows, even if the affection has existed a long time. On the other hand, when the membrana tympani is injured and a suppuration of the middle ear is thereby set up, extensive destruc-tion of the membrane with a high degree of deafness, and even facial paralysis (Stacke), may result. In addition to these sequelæ severe, persistent tinnitus, hyperæsthesia acustica, and con-tinuous headache were observed in one of the author's cases.

That unskilful attempts at extraction may also cause serious complications by injuring the walls of the cavum tympani and labyrinth is proved by the fatal cases of meningitis, abscess of the brain, and sinus thrombosis which have been reported from time to time (Sabatier, Fränkl, Wendt, Lucae, Zaufal, Moos, Lewi, and others).

Diagnosis.—When making an examination, we must first ascertain whether a foreign body is present, as it not infre-quently happens, especially in children who admit having in-

serted some article into the ear, that nothing can be found. In several cases of this kind, the author has seen the meatus and membrana tympani injured by a previous blind attempt at extraction. Pilcher (cited by Th. Barr) and Szokalski have even observed a fatal meningitis and erosion of the carotid artery result from such attempts, and Lucae saw in one case complete deafness follow injury and caries of the inner tympanic wall.

After having established the presence of the foreign body, we should next try to ascertain its size, form, consistency, and position. Frequently a glance is all that is required to recognize the body. Very often, however, especially if the foreign body lies in the deeper parts of the meatus and is covered by a hæmorrhagic exudate and secretion, the diagnosis is very difficult; this at times is made even more so, as children are often unable to state what kind of a body they have inserted into the meatus. If a part of the foreign body is visible, we should ascertain its nature by means of a probe, whether it is hard (stone, glass, metal) or whether it is soft and yielding (beans, peas, carob-stone).

Treatment.—The extraction of a foreign body depends on its seat, consistency, size and form, and on the condition of the meatus at the first examination; in other words, whether no attempts at extraction have been previously made, or whether the meatus has been injured by such attempts, and has become inflamed and narrowed.

The removal of a foreign body from the ear is, as a rule, very easy, provided that no obstacle has been created by a previous faulty attempt at extraction. The latter occurrence is, unfortunately, so often the case that, according to the author's observations, hardly 10 per cent. of the cases which come to the specialist are untouched. In the great majority of cases, the over-anxious relatives, or physicians unfamiliar with aural affections, push the foreign body into the deeper parts, where it becomes impacted and injures the meatus and membrana tympani.

The surest method of removing foreign bodies, and the one most certain of success, is the forcible injection of lukewarm water by means of a large syringe, to the end of which a small piece of india-rubber tubing is attached. By inserting the nozzle with this attachment as far as the foreign body, the strength of the current is considerably increased, and the body is more quickly and surely washed out. When heavy bodies lie in the meatus—for example, grains of shot—Voltolini and Hedinger recommend that the injections should be carried out with the patient lying on his back and the head inclined backwards; by this manipulation the foreign body is supposed to be more easily dislodged from the sinus formed by the drum membrane and the inferior wall of the meatus (*sinus of the inferior wall*). The removal of a body by syringing is often rendered easier by

previously instilling oil or glycerine (Noquet). When foreign bodies which absorb moisture (peas, beans) become impacted, the repeated instillation of alcohol before syringing has proved of great service to the author.

If the body is so firmly fixed in the auditory canal that it cannot be removed by forcible injections, we may try the agglutinative method of Mesue[*] and Löwenberg before resorting to an operative procedure. This consists in first drying the foreign body and then dipping a camel-hair brush of medium size into a concentrated solution of glue, which is introduced into the meatus until it comes into contact with the body. When this thick fluid has dried, the brush adheres so strongly to the body that it can often be removed, provided the resistance is not too great. This procedure is especially applicable to bodies liable to swell, to wooden balls, and to cherry-stones, but cannot be employed if there is inflammatory secretion in the meatus, as this interferes with the drying process of the glue. For pebbles, freshly prepared cement is preferable to glue. If a glass or steel bead becomes impacted with its opening directed outwards, Lucae recommends the introduction of a small moist laminaria tent into its lumen; after half an hour the bead, which is supposed to be attached to the expanded tent, is removed. G. Alexander removed an iron ball from the meatus with a magnet.

Operative Methods.—In reference to the operative removal of foreign bodies, no fixed rule can be laid down as to what procedure to adopt when forcible injections have proved of no avail; the reason for this is that the method to be employed is governed by a number of circumstances which vary in each individual case. Given the fact that the shape of the meatus, its width and curvature, present manifold variations, the relations of the foreign body are still more modified by its size, form, consistency and position, as well as by the possible occurrence of inflammation, swelling, and stricture of the canal; therefore in every case the treatment is determined by a correct judgment of the circumstances, and here, more than elsewhere, the acuteness of the physician is the leading factor in the success of the operation.

In every case in which previous attempts at extraction have been without avail, the physician must well consider whether he should immediately resort to operative measures, or whether he should wait until more favourable circumstances present themselves. If the chances are favourable for its operative removal, it is better to begin at once, especially if the meatus has been injured by previous attempts at extraction, because the inflammation set up by the foreign body may take an unfavourable course. In like manner, immediate operation is indicated in those cases in which a persistent cough or other troublesome reflex symptoms are produced by the presence of the foreign body.

* Politzer, *Geschichte der Ohrenheilk.*, vol. i., p. 43.

It is only advisable to keep the patient under observation in those cases in which the operative procedure is made difficult by a deeply seated foreign body and a simultaneous inflammatory narrowing of the meatus, and in which no dangerous symptoms are present. In such cases, we should first try to relieve the swelling in the meatus by the application of cold compresses and wet dressings of Burow's solution, and by the introduction of powdered boracic acid, or boracic alcohol, and only when the inflammatory swelling has subsided and the body has become visible should steps be taken for its removal. When dealing with complicated cases, especially in children, it is better to undertake the operative removal of the body under slight general anæsthesia.

If the body—*e.g.*, a pea, bean, swollen carob-stone, or wooden ball—is impacted in the narrowest part of the auditory canal, or is firmly and immovably situated before or behind the isthmus owing to great swelling and pressure against the walls of the meatus, the extraction is best accomplished by means of a strong curved hook (Fig. 104), or a firm needle, the lance-like point of which is placed at right angles to its long axis (Fig. 105). The smallest sharp spoons, which are used to remove granulations from Prussak's space, have also proved of advantage to the author in the removal of foreign bodies.

When a body is impacted at the commencement of the osseous meatus, the instrument, fixed to a handle, is introduced in such a manner that the hook or needle is placed in a horizontal position, and is inserted between

Fig. 104. Fig. 105.

the foreign body and the superior wall of the meatus. It is now gently pushed backwards behind the foreign body, whereupon the instrument is turned in such a manner that its point is directed downwards. The handle is lifted upwards so that the point of the hook or needle may deeply penetrate the foreign body; if these precautions are carried out, the body is most easily removed from the auditory canal. When the foreign body is situated at the inner portion of the osseous meatus, it is better to introduce the hook between the body and the anterior inferior wall of the auditory canal; this precaution is of value, because, if it is introduced along the superior wall, the posterior superior part of the membrana tympani might easily be injured.

Burning the foreign body with the galvano-cautery, as recommended by Voltolini, is applicable only in exceptional cases;
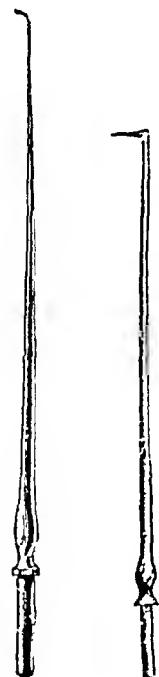
this is not very practicable owing to the extreme pain caused by the procedure, and to the harmful influence which the long-continued radiating heat has on the walls of the meatus.

Our manner of procedure is essentially different in the case of hard bodies—*e.g.*, pebbles, glass beads, pieces of slate pencils, cherry-stones, etc.—than with those liable to swell. If the body is impacted in the cartilaginous meatus, its removal is, in the majority of cases, very easily accomplished if we insert a slightly curved or hook-shaped probe behind the body.

Of the instruments recommended for the removal of foreign bodies, the author has found the fenestrated curette (Fig. 106), the scoop-shaped steel lever of Zaufal, the blunt hook of Lister, the fenestrated forceps of Guye, and the gouge forceps devised by himself as being the most useful. The author must call attention to the fact that the use of the ordinary forceps is to be avoided, as they usually wedge the foreign body into the meatus more firmly.

The operative removal of hard bodies when they are situated in the narrowest part of the auditory canal or behind the isthmus, or have been driven into the tympanic cavity, is much more difficult. This applies especially to those irregular bodies, such as pebbles, pieces of slate pencils, glass beads, etc., which in certain positions easily pass the narrowest part of the canal, and on the slightest movement of the body so change their position that their long diameter is at right angles to the axis of the meatus.

The removal of such bodies from the deeper parts of the meatus, as well as the choice of one of the instruments already mentioned, depends on the size and position of the body, and on the relative capacity of the meatus. In a number of cases, the extraction is very easily accomplished if we are able to loosen the body by careful manipulation with the probe, and thereby change its position.

On the other hand, in other cases in which all attempts at extraction are fruitless, the removal must be postponed until the conditions are more favourable. In extreme cases, however, when dangerous symptoms, such as increased temperature, labyrinthine and brain symptoms,

Fig. 106.

vomiting, optic neuritis or choked disc appear, the removal of the foreign body must not be delayed; the auricle and posterior wall of the cartilaginous section must be detached, and, if necessary, the posterior wall of the osseous meatus must be chiselled away. According to Schwartze (*A. f. O.*, vol. lxx.), long-continued pain is an indication for an operative procedure.

At times foreign bodies which have forced their way into the tympanic cavity do not set up any reaction (hard rubber plugs). Sometimes, however, they bring about violent inflammatory reaction, dizziness and nervous head-ache. If it is impossible in these cases to bring the foreign bodies into the meatus by the use of probes, small levers and injections *per tubam*, nothing remains but to detach the auricle, and eventually to chisel away the posterior wall of the meatus and the external wall of the attic. V. Tröltsch removed a metal ball from the tympanic cavity by means of Wilde's snare.

In a few cases, foreign bodies have been known to enter the tympanic cavity from the naso-pharynx. Urbantschitsch (*Berl. klin. Woch.*, 1878) saw an oat-husk make its appearance in the external meatus after it had passed up the tube into the tympanic cavity.* Schalle (*ibid.*, 1878) reported a case in which, during a nasal doucho by means of a vulcanite syringe, a detached fragment of the latter entered the tympanic cavity, where it set up an acute suppuration, and was removed by incision of the tympanic membrane.

Wagenhäuser reported the case of a boy, six years of age, in whom a piece of straw passed along the tube into the tympanic cavity, where it set up an ichorous suppuration of the middle ear, which rapidly subsided after removal of the foreign body.

Before leaving the subject of foreign bodies, we must still mention insects (such as flies, fleas, bed-bugs, beetles, cock-roaches, etc.) which find their way into the auditory canal. They not infrequently stick in the cerumen, and die in the ear without causing any unpleasant symptoms.

Where, on the other hand, the living insects reach the osseous meatus, and thence make their way to the membrana tympani, they often produce the most violent pains and noises in addition to headache, convulsions and vomiting.

In such cases the insects in the meatus are most rapidly killed by the instillation of oil, after which the ear is washed out with warm water.

Under foreign bodies, we must still mention the larvæ of insects and maggots; these sometimes develop, especially during the summer, in children with a neglected, offensive suppuration of the middle ear, less often, however, with a secretory otitis externa without perforation of the membrana tympani. They often exist for a long time without causing any marked symptoms, but at times they have been known to produce severe pains, and even delirium. Larvæ are best removed by the instillation of oil or glycerine, to which a few drops of petroleum, turpentine or ethereal oil have been added. Several minutes after the instillation, the larvæ leave their place of abode and crawl out into the meatus, whereupon they can be removed by hot irrigations.

* Pifil (*A. f. O.*, vol. lxxii.) saw a fatal termination as the result of a blade of grass boring its way through the walls of the Eustachian tube.

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II.

THE DISEASES OF THE MIDDLE EAR.

The Diseases of the Membrana Tympani.

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Pathological changes in the membrana tympani develop either primarily in the membrane itself or secondary to diseases of the external and middle ear.

Histological Changes in the Membrana Tympani.

I. Changes in the Epidermic Layer of the Membrana Tympani.

In acute inflammations, the epidermic layer of the drum membrane—owing to serous effusion—becomes loosened, puckered, cloudy and opaque; further, this layer becomes covered with ecchymoses which exude from the cuticular layer, and often raise it in the form of bullæ. As a rule, after the inflammatory process has run its course the macerated epidermis is cast off, and a rapid regeneration of the epithelial tissue takes place.

In chronic inflammation of the membrana tympani one often sees an enormous thickening and growth of the epithelial layer; this is especially the case as a sequel to a chronic otitis externa and chronic eczema, and after an otitis media suppurativa has run its course (otitis desquamativa, Buck). The detached epidermic masses consist of swollen and fatty epidermic cells, and of free fat globules and débris, in which one very often finds cholesterine crystals and pigment.
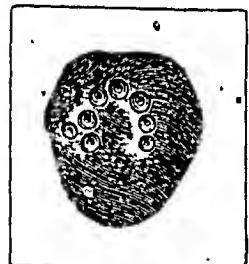
Fig. 107. — Globular Pearly Growths on the Left Membrana Tympani of a Young Man who had had an Affection of the Ear for a Year; a Small Perforation in the Anterior Inferior Quadrant.

In a few cases, circumscribed hypertrophy and cornification of the epidermic layer take place, or, as in a case observed by the author, a pointed, horny growth formed which could not be detached from the membrana tympani. In the course of chronic inflammations of the middle ear, small, pearl-like nodules containing epithelial cells are sometimes formed on the membrana tympani and in the external meatus (Urbantschitsch). According to the author's observations, such conditions are by no means rare after a suppuration of the middle ear has run its course.

The author observed on the superior half of the membrana tympani, in a case of middle-ear suppuration which had run its course (Fig. 107), eight pearl-like protuberances of a bright lustre, which were the size of a pin's head. On probing they

proved to be hard and firmly attached to the membrana tympani; after these nodules had burst, their contents were examined, and found to contain cholesterine crystals and fine-celled detritus. Grunert observed the formation of a cholesteatoma, the size of a pin's head, in a cicatrix following a paracentesis. Küpper saw, in a phthisical patient, a cholesteatoma 1·5 mm. in size situated in front of the umbo.

The opacity of the membrana tympani caused by loosening of the epidermic layer and that brought about by cloudiness of the mucous membrane layer is differentiated by the fact that the handle of the malleus is distinctly visible in the latter case. If, on the other hand, the epidermic thickening be ever so slight, the manubrium is not well defined, and should this thickening increase, even its outline is absolutely invisible. To further support the differential diagnosis, the membrana tympani, in the latter case, appears either flat or uneven, and the boundary between it and the auditory canal is obliterated.

II. CHANGES IN THE CUTICULAR LAYER OF THE MEMBRANA TYMPANI.

Hyperæmia and Hæmorrhage of the Cuticular Layer.

The vessels of the membrana tympani, which are invisible in the normal state, become quite clear when there is a marked hyperæmia; such a hyperæmia may be caused by irritation or inflammation, and may affect either individual parts or the whole of the membrane. In the normal state, a marked hyperæmia can even be produced by a long-continued examination with the speculum, or by mechanical irritation of the meatus. Hyperæmia of the membrane is often accompanied by a simultaneous hyperæmia of the lining of the meatus, but more frequently by a similar condition of the mucous membrane of the tympanic cavity.

Hyperæmia of the membrana tympani always begins with a congestion of the boodvessels running along the handle of the malleus. These vessels, which extend as a red band to the umbo, and which are generally in communication with the injected vessels of the superior wall of the meatus, often cover the manubrium so completely that its location is recognized only by their congestion.* If the congestion of the vessels increases, the vascular wreath, situated near the periphery of the membrane, also becomes injected, and radiating branches extending from here towards the centre of the membrane are seen to anastomose with the vessels extending along the handle of the malleus. Finally, if the hyperæmia still increases in intensity, the capillary meshes of the cuticular and mucous membrane layers become so

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* Compare A. Politzer, *Beleuchtungsbilder des Trommelfells*, 1865, and *Atlas der Beleuchtungsbilder des Trommelfells*, 1898, Plate I., 13 and 14.

of the substantia propria is sometimes unaltered; more often, however, through serous exudation, this layer appears loosened and soft, its fibres being pressed apart and infiltrated with round cells.

The tissue changes in chronic inflammations are more striking; this is especially noticeable in the course of a chronic middle-ear suppuration in which a large quantity of exudate is effused into the substantia propria from the surrounding inflamed layers. Such an infiltration in the membrana tympani appears as an ill-defined, yellowish plaque as long as the suppuration lasts; as soon as the formation of pus ceases, however, it assumes the appearance of a chalky, grayish-white, sharply-defined spot. In an adhesive process which has developed after an exhausted middle-ear suppuration, the membrana tympani becomes thickened and rigid; this is due to a hypertrophy of its layers.

The exudate in the substantia propria is capable of complete absorption; often, however, owing to the slight vascularity of this layer, traces of exudation remain which undergo calcareous metamorphosis. These calcareous deposits are among the most common pathological changes seen on the membrana tympani. They occur most frequently in the course of a chronic suppuration of the middle ear, less often in acute catarrh running its course without the formation of pus. When the chalk deposit is not very thick, which signifies that an amorphous mass is located between the fibres and corpuscles of the membrana tympani, the change is confined to the substantia propria; if, on the other hand, the deposit is of considerable thickness, the internal and external layers of the drum membrane are involved in the process of calcification. In extreme cases, the thickness of the membrane is increased to several times that of the normal; the external surface is smooth, while the internal is uneven, and appears as if it were covered with an uneven layer of plaster of Paris. If such membranes are touched with the probe, they feel hard and non-resistant, similar to an egg-shell. As a rule, the periphery of the drum membrane is not involved in the process of calcification.

When the membrana tympani is considerably thickened, its fibres, which are here and there completely changed, are infiltrated with minute fat globules and punctiform nuclei, so that in microscopic sections the three layers can no longer be distinguished. V. Tröltsch found in one case crystallized chalk deposits; Bauer, in the membrane of hemicephalic individuals, crystals of phosphate of lime. Besides the above, one sometimes finds in the calcified portions black or blackish-brown pigment (Toynbee) arranged either in round groups or bands, or adhering to spindle or star-shaped cells; in addition to this pigment, there is a variable amount of fat globules.

The occurrence of osseous new growths in the human drum

membrane was described by the author in the year 1862,* and later confirmed by Wendt, Habermann and Gruber. In a case which the author had occasion to observe, he found in the calcified membrana tympani of a young man who died of tuberculosis, and who had a discharge from the right ear for some time, a true osseous growth, 0·5 mm. in size, behind the handle of the malleus (Fig. 110).
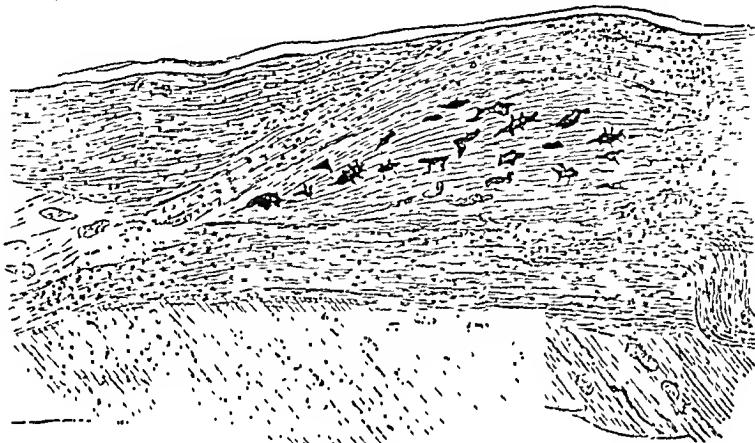
FIG. 110.—OSSEOUS NEW FORMATION IN THE MEMBRANA TYMPANI OF A YOUNG MAN WHO DIED OF PULMONARY TUBERCULOSIS.

Wendt found a reddish, uneven cholesteatoma on the inner surface of a perforated membrana tympani; this mass had a golden lustre, and, according to this author, developed from the substantia propria and the endothelial sheaths. Hinton observed a lamellar cholesteatoma, the size of a pea, above the short process of the hammer. A. H. Buck† reported a case of interlamellar cyst in the membrana tympani.

Changes in the Mucous Membrane Layer of the Membrana Tympani.

In acute inflammations, hyperæmia of the dense vascular network of the mucous membrane layer is accompanied by a simultaneous congestion of the cuticular layer. Ecchymoses in the mucous membrane are most frequently observed in primary, acute inflammations, and in concussions of the membrana tympani. With the process of repair, they may either completly disappear or remain as pigmented spots.‡ Extensively varicosed, lymphatic vessels with saccular expansions have been

* Cp. the author's treatise, *Zur pathologischen Anatomie der Trommelfell-rübungen und deren Bedeutung für die Diagnostik der Gehörkrankheiten. Oesterr. Zeitschrift f. pr. Heilk.*, 1862.

† *Medical Record*, vol. vii., and Roosa's *Diseases of the Ear*. p. 222.

‡ Wendt observed, in patients suffering from variola, the occurrence of small hæmatomata in the mucous membrane of the membrana tympani.

observed by the author in the deeper layers of the mucous membrane of the middle ear.

The exceedingly thin layer of connective tissue of the mucosa, inseparable from the substantia propria, may become hypertrophied to such a degree through tumefaction, growth of round cells, and new formation of connective tissue, that the membrane becomes several times its normal thickness. In chronic suppuration of the middle ear, the increase in thickness of the mucosa leads to adhesion of the membrana tympani to the inner tympanic wall; if, however, adhesion does not take place, it leads to thickening of the membrane. In several specimens the author found only the fibrous framework of the mucous membrane layer hypertrophied (*vide* p. 21), and projecting, in the form of a ridge, above the level of the inner surface of the membrane. In addition, especially in suppurative inflammations of the middle ear, papillary excrescences, large polypoid growths, pedunculated cysts of microscopic size, as well as diffused and circumscribed whitish or pigmented deposits which undergo calcareous metamorphosis, develop in circumscribed parts of the membrane. In one case Lucae found carbonate of lime crystals in the drum membrane.

Tubercles in the substantia propria of the membrana tympani appear as yellowish-red spots a little larger than a pin's head (Schwartze,* Politzer †).

Baratoux is supposed to have observed in a case of syphilis, besides several small gummata on the face and auricle, a small opalescent gumma on the membrana tympani behind the malleus. The case was kept under observation, and at a later period the gumma broke down. Kirschner saw a syphilitic ulcer on the membrana tympani. Lang and Triguet observed papules, with a perforating destruction of the membrana tympani; Todd saw an aneurismal new formation of bloodvessels, Buck a cavernous angioma, and Wagenhäusen a nævus cutaneous venosus which extended to the drum membrane.

The anomalies in transparency and colour, the disturbances in continuity, the healing process of perforations, and the anomalies of curvature, will be fully discussed in the chapters on the different forms of disease of the middle ear.

Inflammations of the Membrana Tympani.

I. PRIMARY ACUTE INFLAMMATION OF THE MEMBRANA TYMPANI. (MYRINGITIS ACUTA.)

Primary acute inflammation of the membrana tympani affects either the entire structure, or it confines itself to a localized area. The inflammation is usually most marked in the posterior half

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* *Handbuch der path Anat.*, by E. Klebs, 1878.
† Politzer, *Atlas der Beleuchtungsbilder des Trommelfells*, 1898, Plate VI., Figs. 8 and 9.

of the membrane; only rarely does the immediately adjoining portion of the posterior superior wall of the meatus become simultaneously involved in the inflammatory process. The cause of a primary myringitis is often unknown. It occasionally develops after the action of a cold wind upon the ear, after cold baths and douches, after sea-baths, after a traumatism, and in children during the course of an acute naso-pharyngeal catarrh. The inflammations of the drum membrane, brought about by scalds, instillations of irritating and cauterizing substances (chloroform, acids, etc.), or by fungous growths, are generally combined with otitis externa.

The hitherto accepted fact that myringitis is always caused by inflammation-producing micro-organisms has been disproved by investigations at the author's clinic. In a number of cases of

FIG. 111.—A BULLA THE SIZE OF A HEMP-SEED IN FRONT OF THE UMBO. FROM A MAN, 24 YEARS OF AGE, WHO HAD HAD AN INFLAMMATION OF THE MEMBRANA TYMPANI FOR TWO DAYS.

On the third day of the disease the bulla disappeared, the membrana tympani was dim and covered here and there with black ecchymotic spots; on the fourth day the power of hearing, which was only slightly lessened during the existence of the bulla, was again completely normal.

FIG. 112.—TRANSPARENT, GLISTENING, PEARLY BULLA IN THE POSTERIOR INFERIOR QUADRANT OF THE MEMBRANA TYMPANI OF A YOUNG MAN WHO HAD AN INFLAMMATION FOR 18 HOURS.

Hearing distance only slightly decreased. On the next day the bulla had disappeared.

primary myringitis, H. Neumann and Ruttin found that the contents of the serous bullæ were sterile. In such cases, therefore, the bullæ formation might be looked upon as a herpetic eruption. In other cases there were found streptococci and pseudo-diphtheritic bacilli combined with staphylococci.

Condition of the Membrana Tympani.—Acute myringitis begins with great hyperæmia of the external layer of the membrana tympani, which is very soon followed by an exudation into its deeper tissue.

The milder forms of myringitis are chiefly confined to the superficial layers of the cutis. When the inflammation is slight there occurs, simultaneously with a redness of the osseous meatus,

a diffuse, vascular injection covering the manubrium, and a serous infiltration of the cuticular layer with scattered, irregular ecchymoses; or one or more transparent bullæ the size of a hemp-seed filled with serous fluid are formed, the lustre and transparency of which give them the appearance of fine mother-of-pearl (myringitis bullosa) (Figs. 111 and 112). The occurrence of hæmorrhagic bullæ on the membrana tympani is most frequently seen in the otitis due to influenza. In a case examined by the author (Fig. 113), the cherry-red, oval bulla was situated on the posterior fold of the membrane; in another case, the dark red tumour occupied the entire posterior superior segment of the membrane.

The duration of such bullæ is generally short; they frequently rupture a few hours after their formation, or disappear through

FIG. 113.—DARK RED HÆMORRHAGIC BULLA UPON THE POSTERIOR FOLD OF THE MEMBRANA TYMPANI OF A MAN 60 YEARS OF AGE, WHO SUFFERED FROM INFLAMMATION FOR 24 HOURS.

On the third day a dry ecchymosis was visible on the site of the blister.
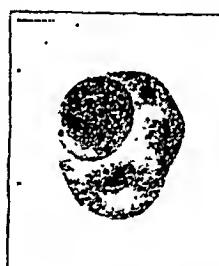
FIG. 114.—TENSE, YELLOWISH, TRANSPARENT, LUSTROUS BULLA, INVOLVING THE POSTERIOR SUPERIOR PORTION OF THE MEMBRANA TYMPANI. FROM A MAN, 21 YEARS OF AGE, WHO HAD MYRINGITIS FOR 36 HOURS.

Two days after the first observation the bulla had disappeared without having burst. The hearing distance, which had been slightly lessened, was again normal after a short time.

rapid absorption of their contents. In the former case a small quantity of watery or sanguineous fluid is discharged for a short time, and, at the spot where the bulla was located, the membrana tympani is seen to be covered with a layer of ragged epidermis; it is pale gray in colour, the hyperæmia at and along the handle of the malleus is decreased, and small ecchymoses are seen around the spot where the bulla was situated.

In the more severe forms of myringitis one sees large bullæ and abscesses which are mostly situated in the deeper layers of the cutis. They occur singly, or in groups, and may recede spontaneously or burst, emptying their contents into the external meatus.

In such cases, inspection shows a swelling the size of a small pea occupying the posterior superior portion of the membrane.

If the swelling contains serum (Fig. 114), it resembles a large transparent pearl of a yellowish lustre; if, on the other hand, the exudate is purulent, the swelling assumes the appearance of a lustrous, non-transparent, yellowish-green bulla. If a more diffuse exudation takes place into the deeper strata of the cuticular layer, the latter will be bulged forward in the form of a bluish-red, lustrous tumour, or as a swelling covered with a slightly torn and moistened epidermic layer, which at first shows great resemblance to a polypoid growth.

The seat of primary abscesses is usually in the posterior superior quadrant of the membrana tympani. In all the cases which have come under the author's observation, he has on rare occasions seen small abscesses on the posterior inferior quadrant and on the anterior half of the membrane. They appear either as hemispherical, greenish, lustrous, non-transparent tumours, or as small, pointed, greenish prominences surrounded by livid, infiltrated or ecchymosed tissue. If the abscess is incised with a paracentesis knife, a drop of pus will exude from the opening.

FIG. 115.—BULLA AND ABSCESS ON THE RIGHT MEMBRANA TYMPANI OF A YOUNG MAN WHO HAD HAD AN INFLAMMATION OF THE MEMBRANE FOR 24 HOURS.

The bullæ and abscesses which arise in the posterior superior portion of the drum membrane generally make up the greater part of the tympanic picture; they spread over and cover not only the handle of the malleus, but also the anterior portion of the membrana tympani. The short process of the malleus generally remains visible as a white knob in front of and above the swelling; the surrounding area is intensely reddened, ecchymotic, and resembles a pustule encircled by a red areola. In one case the author observed, on an inflamed membrana tympani, the formation of a bulla and an abscess at the same time (Fig. 115); the former disappeared on the third, the latter on the fourth day.

Symptoms.—Acute myringitis begins with violent, lancinating pains radiating towards the vertex and the lateral region of the neck, and is sometimes accompanied by subjective noises and pulsation. If the inflammation is confined to the superficial layers of the drum the pain generally lasts a short time, and ceases when bullæ make their appearance. If, on the other hand, exudation takes place into the deeper layers of the membrane, and the latter is bulged out as a bluish-red swelling towards the meatus, or if an abscess is formed, the pain becomes very severe, especially at night, and often continues intermittently for several days until the inflammation subsides. The formation of painless, acute abscesses in primary myringitis is rare. Occasional

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symptoms of primary myringitis are a feeling of fulness, pressure, and uneasiness in the ear, and often great sensitiveness to noises. A slight pyrexia is observed in children, seldom in adults.

The disturbance of hearing accompanying myringitis has no relation to the changes in the membrana tympani. If the hearing is tested at the stage when the exudation is most pronounced, one generally finds only a moderate decrease in the acuteness of hearing for the acoumeter and for whispered speech. In the acute inflammations of the membrana tympani the hearing is, as a rule, but slightly diminished.

Course.—The course of acute primary myringitis is distinguished from that of an acute otitis media by the more rapid decrease in the inflammatory phenomena, and by the much shorter duration of the process. In acute myringitis the normal condition is usually completely restored in three to four days; protracted, frequently relapsing cases are rare. The exudate in the superficial layers of the membrane is either rapidly absorbed, or discharged into the auditory canal by the bursting of the epidermic layer. In the latter case, the place where the bulla was situated is covered by a gray, macerated epidermis, the vessels of the malleus are injected, and the surrounding area of the bulla is ecchymosed. After the bulla has burst there is generally a decrease in the hearing; this is caused by the inflammatory swelling extending from the membrane into the tympanic cavity. Bursting of the abscess into the cavum tympani is extremely rare. In one case, the author was able to diagnose this occurrence by the rapid disappearance of the abscess, and by the pronounced bulging of the collapsed swelling after an inflation of air. The communication between the emptied abscess and the tympanic cavity was proved by the fact that the exudate, which had collected in the lower part of the bulla, was separated from the air in the upper part by a grayish-white line.*

Diagnosis.—The diagnosis of primary myringitis can be positively made only if the case is seen during the first few days of the disease. It is principally based on the fact that, in spite of the marked changes in the membrana tympani, the hearing distance is but slightly diminished. It is possible to confound it only with an acute otitis media. This is due to the fact that the inflammatory phenomena on the membrana tympani are not infrequently similar to those of acute myringitis. A mistake is easily avoided, however, if we bear in mind that in an acute otitis media a copious exudation takes place in the cavum tympani even after the inflammation has existed a short time, and that owing to this the hearing is diminished to a much greater degree. The diagnosis of primary myringitis is much more difficult if the first examination of the patient takes place

* Cp. the author's treatise, *Ueber Blasenbildung und Exsudatsäcke im Trommelfells*, W. med. W., 1872. Politzer's Atlas, Plate I., Fig. 28.

at a stage in which the inflammatory process has extended into the tympanic cavity and the Eustachian tube. In such cases, it is impossible to ascertain whether the inflammation originally began in the membrana tympani or in the middle ear.

Terminations.—Acute primary myringitis generally ends in recovery. Only in rare cases does a chronic inflammation and suppuration develop on the external surface of the membrane, which occasionally goes on to ulceration and perforation. A sequela more often met with is an inflammatory swelling of the lining membrane of the middle ear; this, however, passes away in a short time. From the foregoing, H. Neumann believes that it may be concluded that myringitis is often only the forerunner of a middle-ear catarrh. After the myringitis has run its course, a slight hyperæmia, radiating injection of the vessels and cloudiness of the membrane, together with continuous desquamation of the epidermic layer (*myringitis sicca*, de Rossi), may continue for some time. Changes which may persist in the membrana tympani are finely striped, gray opacities, circumscribed calcareous spots, or patches of atrophic thinning having the appearance of cicatrices.

Treatment.—In the beginning, the treatment of acute inflammation of the membrana tympani is purely palliative—in fact, quite the same as in the acute stage of an otitis media acuta. We therefore refer the reader to the special chapter on the treatment of this latter disease. Only in those cases in which a very painful abscess forms in the membrana tympani should it be opened with a paracentesis knife.* This very simple operation is therefore indicated in these cases, as it prevents the pus from breaking into the tympanic cavity. On the other hand, paracentesis is unnecessary in cases in which the globular hullæ are of a pearly-gray lustre, and are transparent and filled with a serous fluid, because they either quickly subside, or soon after their formation rupture spontaneously, discharging their contents into the meatus. In inflammations of the deeper layers of the membrana tympani, in which it is bulged in the form of a bluish-red swelling, incisions should be made only in those cases in which, on account of violent pain, a diminution in tension in the infiltrated portions of the membrane is rendered necessary. After the incision, the edges of the wound close quickly, and it is only in rare cases that a protracted discharge of pus takes place.

In acute myringitis the use of the air-douche is indicated only when a rapid decrease in the hearing takes place after the pain has disappeared. From this fact we may infer that the affection is associated with a simultaneous swelling and secretion in the middle ear. In such cases, an inflation of air, after the method of the author, is generally sufficient to re-establish the hearing

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* The details of paracentesis of the membrana tympani will be given in the section on the Treatment of Sero mucous Middle Ear Catarrh.

function, and should be continued once a day until the deafness disappears. In those rare forms of myringitis associated with purulent exudation on the membrane, frequent syringing with some cleansing solution, or with a normal saline solution, followed by the insufflation of a small quantity of finely-powdered boracic acid, is generally sufficient to stop the secretion.*

II. Chronic Inflammation of the Membrana Tympani. (Myringitis Chronica.)

Etiology.—Chronic myringitis is a very rare disease of the ear. It arises from primary acute myringitis, and generally after an extensive inflammation of the cuticular layer. As a result of such an inflammation, especially in tubercular and cachectic individuals, a permanent suppuration is established on the external surface of the membrana tympani. It sometimes occurs as an insidious affection, without any previous reactive phenomena. According to the author's observations, it is more frequently a sequel of an otitis externa after the changes produced by the inflammation on the walls of the meatus have disappeared. In like manner, the author has repeatedly seen the symptoms of a chronic inflammation of the drum membrane persist after the cessation of a middle-ear suppuration, and after the closure of a perforation.

Chronic myringitis affects the entire surface of the membrane, but is sometimes, however, limited only to circumscribed parts. It is most frequently confined to the posterior superior portion, and next in frequency to the region of Shrapnell's membrane. These localized inflammations are only seldom confined to the membrane alone; often a circumscribed portion of the immediately adjoining posterior superior wall of the osseous meatus is involved in the inflammatory process.

Condition of the Membrana Tympani.—In the milder forms of diffuse myringitis the membrane appears grayish-white, moist and lustrous, covered with secretion, and studded with indistinct yellowish-white spots. Through the thin layer of secretion, the congested vessels of the manubrium and the processus brevis can still be plainly seen. On the other hand, when proliferation and thickening of the epidermic layer take place, the membrane is covered with a whitish-yellow, non-transparent epidermic layer which completely masks the malleus, and which is removed with great difficulty by syringing. In such cases the greatly swollen cuticular layer appears intensely congested, flattened and velvety after desquamation of the epidermis, and irregular reflections of light are seen scattered over its surface. When the epidermic layer is partially detached, the congested areas may be mistaken for ulcers of the membrana tympani.

* For myringitis crouposa, see the section on Otitis Externa Crouposa et Diphtheritica (p. 203).

Chronic myringitis sometimes leads to the formation of papillary excrescences (*vide* p. 251); they appear as light red papillæ, the size of a pin's head or hemp-seed, and may either occur singly, in groups (Fig. 116),* or in great numbers over the entire membrane. In the latter case, the membrane has the appearance of a purple raspberry, with numerous dots of light scattered over it. At times the papillary formation extends from the posterior superior quadrant of the membrane to the posterior superior wall of the osseous meatus.

Diagnosis.—The changes perceptible on the drum membrane during an inflation of air are important for the diagnosis of primary chronic myringitis. When Valsalva's method or that of the author is employed, the membrane becomes bulged outwards and the characteristic perforation sound is absent; the granulating surface is freely movable when examined with Siegle's speculum. By this means chronic myringitis is differentiated from chronic suppuration of the middle ear accompanied by perforation of the membrana tympani. In such cases an important aid in diagnosis is further afforded us by means of the auscultation tube, inasmuch as the auscultation sound indicating swelling and secretion in the middle ear is absent. A fact also worthy of notice is that in chronic myringitis the acuteness of hearing is only slightly diminished. Another disease which must be mentioned, and which may be confounded with chronic myringitis, is chronic, non-perforative middle-ear catarrh accompanied by the

Fig. 116.—Granulations on the Membrana Tympani of a Young Girl who suffered for Several Years from Discharge from the Ear.

Removal of the growths by touching them with liq. ferri sesquichlor.

simultaneous appearance of secretion on the external surface of the membrane.

Symptoms.—Chronic myringitis runs a painless course; the patients occasionally complain of lancinating pains and of a feeling of fulness and pressure in the ear. The most troublesome symptoms are the severe itching and the offensive smell which is caused by the decomposition of the cerumen mixed with pus; this alone often induces the patient to seek medical advice.

Terminations.—The terminations of chronic myringitis are: Recovery after the secretion has ceased, or a slight disturbance of hearing if a moderate thickening of the membrane has remained after cessation of the suppuration. The author has seldom observed in the primary chronic forms an excessive thickening of the membrane associated with a high degree of deafness. After

* Politzer's Atlas, Plate I.

the secretion has ceased, there is sometimes a marked desquama-tion of the epidermis (*myringitis desquamativa*, Gottstein), or the formation of crusts on the membrane, which may continue for some time. In myringitis granulosa, the suppuration is kept up by the papillæ, so that a cure is attained only after their spon-taneous healing, or after their removal. The formation of perforating ulcers is a rare sequel.

Treatment.—The treatment of chronic myringitis depends on the pathological changes which have taken place in the mem-brana tympani. If the secretion is accompanied by only a slight swelling of the cutis, it may be stopped by washing out the meatus several times with an antiseptic solution (lysol, or a normal saline solution), followed by the insufflation of finely-powdered boracic acid (compare Treatment of Acute Suppurative Inflammation of the Middle Ear). If the secretion does not decrease after the use of boracic acid, or after the instillations of peroxide for several days, we should then resort to a solution of boracic alcohol (1 : 20), or to a solution of carbolic acid in alcohol (1 : 30), of which a few drops are poured into the ear and allowed to remain for five or ten minutes. These instillations are to be used four to five times a day, and continued until the discharge ceases.

In cases which are specially obstinate, a concentrated solution of silver nitrate (R. nitr. argent cryst. 0·8, aq. dest. 10·0) has proved very beneficial. Attention must be called to the fact that after each application the solution is to be neutralized by washing out the meatus with a salt solution. The instillation should be repeated only when the crust has been thrown off; three applications a week, for three or four weeks, are generally sufficient to stop the formation of secretion on the membrana tympani. The desquamative forms are the most difficult to cure. In such cases, continued instillations of alcohol act better than solutions of silver nitrate. Ulcerations often heal very rapidly after the insufflation of iodoform or iodol; touching the surface of the ulcer with a caustic is seldom necessary to effect a cure.

When granulations have formed on the membrana tympani (*myringitis granulosa*), touching the parts with liquor ferri sesquichloride, after having previously applied powdered cocain, is the most effective treatment. The drug is applied to the growths by means of a probe dipped in the fluid, or by painting them with a small cotton applicator; this procedure is continued every third day until the drum is smooth and dry.

Cauterization with nitrate of silver or chromic acid is far less beneficial, and often causes severe pain. On the other hand, cauterization by means of the galvano-cautery, after having previously cocainized the parts, may be highly recommended, as it produces little pain and shortens the time of treatment. Only in those cases in which cauterization fails is it necessary to remove large growths with Hartmann's small forceps (*vide* operative treatment of aural polypi), and to touch the parts with a caustic.

Stetter describes an insidious, dry inflammation of the membrane, which he designates as *myringitis chronica sicca*. The peculiarities of this disease are that it leads to thickening of the membrana tympani, that it runs its course without secretion and without the formation of granulations, and that it gradually leads to deafness. The drum membrane appears cloudy, lustreless, and the handle of the malleus ill-defined. For treatment Stetter recommends the instillations of acid. sozoiodol 0·25, spirit. vini absolut. 1·0, ol. ricini 10·0.

Traumatic Lesions of the Membrana Tympani.

Traumatic lesions of the membrana tympani are produced—

1. By the direct penetration of a foreign body into the membrana tympani.

2. By the extension of a fracture of the cranial bones to the membrane.

3. By a sudden condensation of the air in the external auditory canal or in the tympanic cavity, more rarely by a rapid rarefaction of the air in the meatus.

1. Direct injury of the membrane occurs mostly in those persons who scratch the auditory canal with different objects to relieve an unpleasant itching, and who, by accident, pierce the membrane with such articles as ear-picks, hair-pins, tooth-picks, pieces of straw, lead pencils, etc. It may also be produced by the careless manipulation of syringes with long, pointed nozzles, by coarse attempts at extraction of foreign bodies, by splinters of wood accidentally flying into the meatus, by a thorn entering the auditory canal while passing through a thicket, by the sudden entrance of water into the meatus (diving), or by throwing snowballs (Schwartze). A strongly retracted membrana tympani may be penetrated by a bougie introduced into the tympanic cavity through the Eustachian tube.

The site, size and form of these injuries vary greatly. According to the investigations of Zaufal on the cadaver (*A. f. O.*, vol. viii.), they depend more or less on the spiral twisting of the auditory canal; furthermore, on the character of the instrument, whether its penetrating end was sharp, blunt, pointed, rigid or flexible, smooth or rough, and, finally, on the force with which it entered the meatus. Ruptures from direct penetration take place more frequently in the posterior than in the anterior half of the membrane.

The condition of the membrane varies according to the extent of the destruction, and according to the time at which the examination is made. In those cases in which the injury is quite recent, and in which the penetrating body was a thin, pointed instrument, one finds an irregular opening, the margins and surrounding tissue of which are covered with blackish-red extravasated blood. When the rupture is extensive and irregular, the shape of the opening is not recognizable, on account of the extravasated blood covering the membrane. In such cases

it is sometimes possible to see the extent of the destruction only at the commencement of the suppuration, and after the extravasations have been removed.

At the moment the membrana tympani is injured there is a loud subjective sound accompanied by a piercing pain, which is followed by fainting or by a marked reeling, dizziness and tinnitus. After several hours the patient feels better, but the dizziness and tinnitus still continue for a considerable time. If a reactive inflammation sets in, the pain and noises in the head again increase in intensity, and may continue long after the cessation of the inflammation. In a case observed by Delstanche—namely, that of a young girl—there were present, two years after the injury of the membrana tympani with a knitting-needle, total deafness, intolerable tinnitus, and severe attacks of dizziness. In this case there was an adherent cicatrix on the posterior superior quadrant of the membrane.

Injuries produced by direct action seldom heal without the intercurrence of inflammation and suppuration. In cases of extensive, irregularly-shaped ruptures, a painful suppuration of the middle ear, lasting for weeks and months, may occur, in consequence of which a secondary inflammation of the external meatus and mastoid process may develop. After cessation of the suppuration, permanent gaps or cicatrices not infrequently remain in the membrana tympani, which frequently adhere to the inner tympanic wall, and often occasion persistent deafness. In cases in which, at the time of the injury, the stapes is also dislocated, there is a continuous vertigo and tinnitus, followed by a total deafness. In reference to the treatment of these cases, the author refers the reader to the treatment of acute perforating inflammations of the middle ear.

2. Ruptures of the second class—that is, those occurring by the extension of a fracture of the cranial bones—often involve the membrane to a considerable extent. The rupture generally takes place from a fissure in the superior or anterior wall of the meatus. The copious bleeding from the ear arises partly from vessels of the membrana tympani, and partly from the fractured bones. A simultaneous fracture of the labyrinth is associated with a flow of cerebro-spinal fluid from the ear. The contour of the rupture varies from that of a long tear to an irregularly-shaped opening. In such cases, the rupture of the membrane is only of secondary importance as compared with the injury of the cranium. Where death does not occur, profuse suppuration, proliferation of the inflamed membrana tympani and of the mucous membrane of the middle ear, and adhesion of the remnant of the membrana tympani to the inner tympanic wall take place.

3. Ruptures of the membrana tympani due to sudden condensation or rarefaction of the air in the external meatus are most frequently caused by a slap on the ear (box on the ear, fist-

blow); also by a fall on the ear; by the report of a cannon, or a gun fired near the ear; by the bursting of a shell; by explosions; by intense concussions in consequence of a stroke of lightning; in caisson-workers, in aeronauts; and by the blowing of brass instruments. Should the air be suddenly condensed in the external meatus, a rupture of the membrane is more likely to take place if the Eustachian tube is obstructed, because the air condensed in the middle ear cannot escape into the pharynx; ruptures are, furthermore, favoured by atrophy, cicatricial formation, and by the presence of chalk deposits in the membrane. Ruptures brought about by the rarefaction of air in the external meatus (kiss upon the ear, aeronauts, therapeutic rarefaction) are, on the whole, rare. Non-penetrating tears—that is, those involving only the cuticular or mucous membrane layer—have been observed only in a few cases. As ruptures of the membrane

FIG. 117.—RUPTURE OF THE ANTERIOR INFERIOR PART OF THE MEMBRANE IN A BOY AFTER A BOX ON THE EAR.
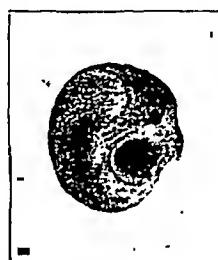
FIG. 118.—A TRIANGULAR RUPTURE, THE EDGES OF WHICH ARE COVERED WITH ECCHYMOSES, IN A MAN 52 YEARS OF AGE FOUR DAYS AFTER A BOX ON THE EAR.

caused by blows in the region of the ear claim the interest of the practitioner from a forensic standpoint, we will first describe these in detail.

At the time of the blow (box on the ears) the rupture in the drum is associated with a violent report or an intense pain in the ear. The patient is frequently seized with such a reeling, dizziness and tinnitus that he is unable to stand. These symptoms decrease in intensity after a few hours; still, subjective noises and a feeling of stupor often remain for several days or longer.

The objective examination of the membrana tympani is of the greatest importance. The condition of the membrane is so characteristic in the first days after the injury that one is able, even with a little experience, to state from inspection alone whether the perforation was caused by an injury or by a pathological process.

The rupture is more frequently situated in the anterior inferior than in the posterior portion of the membrane, and it is generally

ruptured only at one place, seldom at two. An important fact is that the perforation is situated midway between the manubrium and the tendinous ring; only rarely does it extend from the handle of the malleus to the tendinous ring. Shrapnell's membrane is seldom ruptured.

The shape of the rupture is round, as if a piece of the membrane had been punched out; in the case of large ruptures it is often triangular. As a rule, however, it is oval with pointed (Fig. 117) or rounded extremities, the longitudinal axis of the oval usually lying parallel to the direction of the radiating fibres. Irregular, ragged ruptures, or linear tears with non-separable edges situated in front of or behind the manubrium, are seldom seen. In one of the author's cases, the ecchymotic edges of a ragged rupture were so much retracted towards the periphery of the membrane and the handle of the malleus that a large portion of the promontory was visible.

The margins of the rupture are sharply defined, and are covered either in their whole extent or only here and there with reddish-black coagulated blood. Sometimes one sees in the neighbourhood of the rupture (Fig. 118), especially at the posterior edge of the manubrium, ecchymoses and a marked injection of the vessels of the malleus and its surrounding area. At times small coagula are found in the external auditory canal. A striking fact, in a traumatic rupture, is that the inner wall of the tympanic cavity presents its normal whitish-yellow colour without any noticeable vascular injection.*

An important point in deciding whether the rupture is of traumatic origin is the auscultation sound heard when the patient performs a Valsalvan experiment. In cases of extensive pathological perforations, the air usually escapes from the ear with a sharp hissing noise, while in traumatic perforations one hears the air passing through the ear with a very broad, deep breathing sound, provided the injury has occurred in a normal organ. A diagnostic fact worth remembering is that in traumatic ruptures far less pressure is required to force the air through the opening in the membrane than in pathological perforations. It is only when the rupture has caused an inflammatory reaction in the tympanic cavity that the perforation sound is of a high, hissing character.

The disturbance of hearing caused by traumatic ruptures is generally slight. Here, as in all cases in which there is an obstruction in the sound-conducting apparatus, the power of

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* The author's article, *Über traumatische Trommelfellrupturen mit besonderer Rücksicht auf die forensische Praxis* (*Wiener med. Woch.*, 1872, Nos. 35 and 36), was the first to appear on this subject; in this article, the subject is treated according to the present methods, both from an otoscopic and clinical standpoint. Later publications often used this information without mentioning its source.

perception, through the air for the lower part of the scale is diminished. Given the fact that a traumatic perforation is present, a high degree of deafness occurs only when the blow has caused a concussion of the labyrinth; in such cases the power of perception for the upper limit of the scale is also diminished. A sudden condensation of the air in the external meatus may spend its force in two different ways. If the active force of the blow is exhausted on the membrana tympani, a rupture of its fibres is produced, but the labyrinth, as a rule, remains uninjured. In these cases the power of hearing for speech and for the acoumeter is generally but slightly lessened, and the tone of a tuning-fork placed upon the vertex is lateralized only towards the injured ear. If, on the other hand, the membrane remains intact, the main force of the blow is exerted upon the labyrinth, inasmuch as the chain of ossicles, suddenly forced inwards, causes a concussion and paralysis of the endings of the auditory nerve; as a consequence, severe deafness and continuous subjective noises remain. According to the author's observations, the prognosis of these cases is always unfavourable. If there is a positive Rinne, the perception for the tone of a tuning-fork placed upon the vertex is generally localized in the normal ear.

The process of repair of ruptures of the membrana tympani not complicated with concussion of the labyrinth is, as a rule, favourable, in so far as the orifice in the membrane closes again without any marked reactive phenomena. The time it takes for such a rupture to close up varies from three to fifteen days. Judging from the appearance of the membrane, cicatrization often begins in the mucous membrane layer, inasmuch as, several days after the rupture, a grayish-yellow membrane forms over the opening from within, while the edges of the tear in the cutis are still visible for some time. Closure of the rupture less often takes place by a uniform growth of the epidermis, or by a simultaneous growth of all the layers of the membrane.

The coagulated blood adhering to the margins of the rupture either falls off or migrates towards the periphery of the membrane into the osseous meatus. It is only after several weeks that the membrane presents its normal appearance; occasionally a thin cicatrix remains at the ruptured spot.

A rare sequela of traumatic ruptures is the development of a suppurative inflammation of the middle ear. When such an inflammation is produced, it is generally brought about by irrigations, or by the instillation of irritating oils or other medicated solutions. These suppurative processes seldom end in complete cure. More often they lead to a destruction of the tissue of the membrane, to the formation of granulations on the membrane and in the tympanic cavity, to adhesions between the membrana tympani and the promontory, and to the epidermization of the margins of the perforation causing a permanent opening. In

most cases the disturbances of hearing caused by . traumatic ruptures disappear completely; in uncomplicated ruptures, disturbances of hearing and tinnitus seldom remain. Only in those cases in which permanent changes are developed in the middle ear in consequence of a secondary suppuration, or in which the rupture is combined with concussion of the labyrinth, do disturbances of hearing of different degrees, cephalalgia and tinnitus sometimes remain. We have stated above that a blow in the region of the ear may produce a concussion of the labyrinth without a rupture of the membrana tympani. In these cases, which are associated with tinnitus and hardness of hearing, the function of hearing may again become quite normal after several days or weeks; more frequently, however, the disturbance of hearing remains permanent. Besides the varying degrees of disturbance of hearing, the author has frequently observed continuous nervousness, heaviness of the head, and mental depression follow a shock to the organ of hearing.

In the treatment of ruptures of the membrane all local applications must be avoided; experience has shown that through instillations of medicated solutions, syringing the ear, or the use of the air-douche, a cure is not only prevented, but even retarded. Our treatment is simply limited to the closure of the external auditory orifice with sterilized cotton in order to protect the exposed mucous lining of the tympanic cavity from infection. In cases of concussion of the labyrinth, internal treatment or local medication is of little avail; electric therapy with the galvanic current sometimes brings about a relief of the subjective noises, and a cure of the disturbance of hearing if the changes in the labyrinth are not of a serious nature.

Traumatic Ruptures of the Membrana Tympani from a Medico-Legal Point of View.—The absolute diagnosis of a traumatic rupture of the membrane is possible only if the case is seen during the first few days after the injury has taken place. If the examination of the coagula removed from the ear shows a transition into hæmatin and hæmoxylin, we may conclude that the rupture has existed a few days. If the examination is made a considerable time after the infliction of the injury, the physician, owing to a possible cicatrization of the rupture, may not be able to determine whether a rupture had taken place at all, and whether the existing disturbance of hearing has really been produced by the injury.

Again, a rupture of the membrane cannot be said to be of traumatic origin if, at the time of the first examination, a suppurative inflammatory process has taken place in the membrana tympani and in the middle ear. In such cases the condition of the membrana tympani does not differ from that found in a primary suppurative process of the middle ear.

The medical expert is therefore justified in declaring the rup-

ture to be of a traumatic nature only if, in the first few days after the injury, the above-described almost characteristic conditions of the membrane are present, and if, on observing its further course, cicatrization takes place in a few weeks. The latter is of importance, because to one of inexperience a persistent gap produced by a previous purulent process might be mistaken for a traumatic rupture. Such a mistake will not, however, occur if the physician bear in mind that a gap caused by a previous suppuration, when once its margins are covered with epidermis, will never close. The author wishes to state that traumatic ruptures have only two terminations: they either cicatrize during the first few weeks without any complications, or they are combined with a suppurative inflammation of the middle ear.

If the medical expert has declared the rupture in the membrana tympani to be of a traumatic nature, another question to be answered is whether the injury is a slight or a severe one.

An injury of the membrana tympani is to be accounted slight if it is not complicated with concussion of the labyrinth, and if, after cicatrization of the rupture, apart from the duration of the process of cicatrization, the function of hearing returns to its normal state.

On the other hand, an injury of the membrane must be considered severe if, by the blow upon the ear, a simultaneous concussion of the labyrinth takes place. In these cases, to absolutely establish the diagnosis of a paralysis of the auditory nerve, we must take into consideration the results of the various tests. Is there a high degree of deafness for the acoumeter, watch and speech ? Is the tone of a tuning-fork placed on the vertex lateralized in the non-affected ear ? Is the tick of a watch placed against the temple diminished in intensity or absolutely imperceptible ? And is there a shortened perception for the tone of the tuning-fork through the cranial bones ? Stress must be laid on the fact that the results of testing the hearing can be of use to the medical expert only if, through repeated examinations, simulation or exaggeration is excluded (compare chapter on Simulation).

An injury of the membrana tympani must also be considered severe if the rupture has been proved to be of traumatic origin, and if a suppurative process ensues which, through tissue changes (granulations, adhesions), causes a permanent disturbance of hearing.

From the foregoing it is obvious that the medical expert is not always able, in complicated cases, to come to any conclusion from his first examination as to the severity of the injury, and that, in many cases, an observation extending over several months is necessary. The reason for this is that we cannot exclude the possibility of even the most complicated injuries (suppuration, concussions of the labyrinth) healing after weeks or months without any disturbance of hearing.

In reference to those cases in which no perforation of the drum takes place and in which the disturbance of hearing following a blow on the ear is caused by concussion of the labyrinth, the medical expert cannot decide whether, in a given case, the disturbance of hearing was occasioned by an injury or not, inasmuch as the appearance of the membrana tympani, as well as the other characteristic conditions, do not give us any definite data. In such cases the physician must always bear in mind the possibility of a pre-existing chronic affection of the labyrinth or middle ear, which the alleged injured person may, after a quarrel, use as the ground of an action. If the physician finds, shortly after the alleged injury, chalk deposits and cicatrices on the membrana tympani, he may conclude with certainty that he is dealing with a chronic process of the middle ear, as such changes require a considerable time to develop.

According to Wilde, Ogston and Littré, ruptures of the drum membrane may be caused by hanging; they appear to occur more frequently in those who have been executed than in those who have committed suicide by hanging.

The Diseases of the Tympanic Cavity, the Eustachian Tube, and the Mastoid Process.

General Remarks.

The pathological examinations of the organ of hearing made during the last few years have brought to light facts of the greatest importance—namely, that in the majority of ear diseases the primary pathological cause of the disturbance of hearing has its seat in the middle ear, and that the primary diseases of the auditory nerve are of less frequent occurrence.

Diseases of the middle ear originate in the mucous membrane lining; from here those inflammatory changes start which not only often disturb the hearing, but not infrequently extend to neighbouring vital organs, and endanger the life of the patient. The knowledge of these changes is therefore of great importance, as they form the basis for the diagnosis and treatment of middle-ear affections.

The inflammatory processes of the lining membrane of the middle ear and their terminations show, in general, the same character of inflammation as in mucous membranes of other organs. There is, however, one difference which is almost characteristic, and that is that, in the middle ear, thickening of the tissues and adhesions of the diseased surface are of more frequent occurrence than in the mucous membranes of other organs. We therefore find, in inflammations of the lining of the middle ear, the same changes as occur in other inflamed mucous membranes —for example, hyperæmia and serous infiltration, as well as

tumefaction and excessive swelling through exudation and infiltration with round cells; furthermore, free exudate from the surface of the diseased mucous membrane in the form of serous, mucous or purulent secretion; and, lastly, as secondary diseased products, a variable amount of granulations and organized connective tissue which develop in the middle ear during the course of the inflammatory process, and remain as thickenings or bands of connective tissue.

Inflammatory processes in the middle ear show great anatomical as well as clinical variations. Their course is either acute, sub-, acute or chronic; they may heal with complete restoration of the normal hearing, or they may produce deafness of a varying degree due to the development of permanent diseased products.

If we regard the inflammations of the middle ear according to their leading clinical features, we first meet with a large group of affections called, in a strict sense, catarrhs of the middle ear. This group is accompanied by hyperæmia and swelling of the mucous membrane, and is characterized by the discharge of a serous or of a tough, colloid, transparent, mucous secretion. This affection of the mucous membrane, which generally runs its course without notable phenomena or lesions of the membrana tympani, may either completely subside, or adhesions between the membrana tympani, ossicles and walls of the tympanic cavity may form during the course of the disease. These adhesions are brought about by connective-tissue formations in the mucous membrane, inflammatory thickening and contraction of mucous membrane folds, and by connective-tissue bands in the tympanic cavity, which create hindrances to the sound-conduction of a varying degree. They are designated as catarrhal adhesive processes of the middle ear.

Another form of disease, anatomically different, and also ending with a marked obstruction in the sound-conducting apparatus, is otosclerosis. In the true forms of otosclerosis we are not dealing with a diseased condition of the mucous membrane of the middle ear, but with a primary affection having its seat in the labyrinthine capsule; this leads, through new formation and growth of osseous tissue, to ankylosis of the stapes in the fenestra ovalis, and, in the severest forms, to an osseous closure of the oval window. These processes run their course with progressive deafness, have an unfavourable prognosis, and were formerly known as ' dry catarrh.' Their only relation to adhesive processes of the middle ear is that in both cases we are dealing with an obstruction in the sound-conducting apparatus; we must not lose sight of the fact, however, that a mixed form may sometimes occur —that is, a combination of a catarrhal adhesive process and otosclerosis.

In a second group, clinically different, the inflammation of the mucous membrane develops with more or less acute reactive

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(a) The Exudative Form of Middle-Ear Catarrh.

(Syn. : Sero-Mucous Middle-Ear Catarrh.—Otitis Media Serosa.—
Exudative Catarrh.—Middle-Ear Catarrh.—Catarrh of the
Tympanic Cavity and Eustachian Tube.)

Etiology.—The catarrhs of the middle ear which run their course with a discharge of serous or mucous exudate develop as the result of atmospheric changes, colds, the entrance of irritating fluids and vapours from the naso-pharynx into the Eustachian tube—further from influenza, typhoid fever, the acute exanthemata, Bright's disease, and syphilis of the naso-pharynx; they are most frequently due, however, to the extension of acute or chronic catarrhs from the naso-pharynx, and in children to adenoid vegetations. Besides the above etiological factors, sero-mucous exudation is produced by a paralysis of the muscles of the palate and tube caused by a paralysis of the facial nerve after diphtheria, and by atresia and pressure of new growths upon the tube.

Exudation into the tympanic cavity is most frequently caused by the inflammatory process of the mucous membrane itself. Nevertheless, it is beyond doubt that sometimes in excessive swelling of the tubal mucous membrane and impermeability of the Eustachian tube there occurs, in consequence of the consecutive rarefaction of the air in the tympanum, a transudation of serous fluid which is free from bacteria (Scheibe, Süpfle).*

In the sero-mucous catarrhs the affection extends mostly over the entire surface of the middle ear. Still, we must not lose sight of the fact that in acute catarrhs which extend from the naso-pharynx the swelling and hypersecretion may be limited to the lower portion of the Eustachian tube, without extending into the tympanic cavity. These are the cases of intumescence of the pharyngeal orifice of the tube, which are associated with hypersecretion, and which occur in the course of an acute or chronic naso-pharyngeal catarrh. They are seldom primary. In some people a recurrence takes place with every cold in the head. These peculiar catarrhs may remain as a local affection, and heal without any disturbance of hearing, or they may extend immediately, or after the occurrence of frequent relapses, into the tympanic cavity.

In the so-called ' chronic catarrhs of the tube ' which are often observed in children, and which are accompanied by a high degree of deafness, impermeability of the tube, and marked retraction of the membrana tympani, the disease is by no means

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* According to the investigations of Lannois (*Ann. d. mal. de l'oreille,* 1896) and Brieger (*Klin. Beitr. z. Ohrenheilk.*, 1896), the tympanic cavity is free from bacteria in the normal state.

confined to the tube itself, but is, as a rule, spread over the entire mucous membrane of the middle ear.. Therefore, the tubal catarrhs can rarely be separated clinically from catarrhs of the middle ear; and one is justified in speaking of a ' catarrh of the tube ' only if, from the symptoms, the inflammation can be localized in the tube itself without the tympanic cavity being involved in the process.

Condition of the Membrana Tympani.—The condition of the membrane in the sero-mucous catarrhs of the middle ear presents many variations depending on the duration of the affection, on the transparency of the membrane, on the quantity, character, and colour of the exudate, and on the degree of hyperæmia of the mucous membrane of the tympanic cavity.
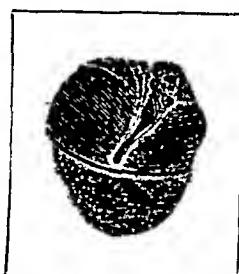
Fig. 119.—Accumulation of Fluid in the Inferior Portion of the Tympanic Cavity, marked by a Bright Line, in a Young Man during the Course of a Severe Cold in the Head.

Cured by Politzerization.

Fig. 120.—Accumulation of Effusion in the Inferior Portion of the Tympanic Cavity, in a Woman, 50 Years of Age, and Syphilitic.

The line of the fluid level is curved and wavy. Removal of exudation by paracentesis.

When the membrane is transparent, the accumulation of serous or mucous exudate in the tympanum can be distinguished by a peculiar, almost characteristic, picture.* If the amount of secretion which has collected in the lower part of the tympanum is small, it will be seen to shine through the membrane as a yellowish fluid, and separated from the upper air-containing space by a sharply-defined line on the drum membrane.

This dark gray or black, sometimes white (Fig. 119), line on the membrane is either concave (Fig. 119), convex, or wavy (Fig. 120), or it assumes the shape of a triangle (Fig. 122), the apex of which is directed towards the umbo. Frequently, the line of the fluid is visible only in front of (Fig. 123) or behind the manubrium, or, by certain kinds of illumination, it appears

* Politzer, *Diagnose und Therapie der Ansammlung seröser Flüssigkeit in der Trommelhöhle. Wien. med. Woch.,* 1867. *Ueber bewegliche Exsudate in der Trommelhöhle. Wien. med. Presse,* 1869. *Atlas der Beleuchtungsbilder des Trommelfells,* Plate II.

as a number of irregular lines which after a short time either change their position or disappear altogether. The colour of the membrane below the level of the fluid is dark and yellowish; above the line it is light gray. As a rule, the yellowish colour of the exudate is more pronounced when it is serous or syrupy than when it is viscid.

When there is a collection of serous fluid in the tympanic cavity, the line seen on the membrane changes its position more or less rapidly when the head is bent forwards or backwards, inasmuch as the fluid flows towards the lowest portion of the tympanic cavity (Fig. 121). If the exudate is a thick mucus, or if the quantity is very small, the line, as a rule, remains unchanged.

FIG. 121.—CHANGE OF POSITION OF THE LINE OF THE FLUID LEVEL OF THE EXUDATE BY INCLINING THE HEAD BACKWARDS.

This is the tympanic picture of the same woman as in Fig. 120.

FIG. 122. — ACCUMULATION OF A SLIGHT QUANTITY OF EXUDATION IN THE INFERIOR PORTION OF THE TYMPANIC CAVITY, IN A MAN WITH AN ACUTE CATARRH OF THE NASO-PHARYNX.

The level of the exudation is bounded by two lines meeting at the handle of the malleus. Cure in three days after the application of the author's method.

If there is a copious collection of secretion in the tympanic cavity, the line on the membrana tympani indicating the level of the fluid will be absent, and the secretion is recognized only by the peculiar yellow, greenish-yellow, or reddish-yellow colour of the membrane itself. This yellow colour is most marked behind the umbo; and it is so characteristic that, with little experience, one can make the diagnosis of an accumulation of serous or mucous secretion in the tympanic cavity by it alone. A point worth bearing in mind is that not infrequently the line appears on the membrane only after an inflation of air. It is important to remember that in all these conditions the membrana tympani has a deep colour, its lustre is increased, and the handle of the malleus is much more sharply defined than in the normal state.

If an inflation of air is given when the accumulation in the tympanic cavity is serous, a number of rings, due to the forma-

tion of froth, and having a black or lustrous contour, appear on the membrane (Fig. 124). If the fluid is thin, these rings show an active motion and rapidly change their position. At times, immediately after an inflation of air, one sees at the anterior inferior margin of the drum one or more air-bubbles which, sometimes slowly, sometimes rapidly, pass upwards out of the line of vision. If the retracted but still lustrous membrane becomes dim, gray, and non-transparent after an inflation of air, the exudate and the bubbles will not be seen. This condition is similar to that seen in those cases in which the tympanic cavity is full of secretion, and in which the diagnosis cannot be made by inspection, because the membrana tympani has become cloudy and opaque owing to a long continuation of the catarrh.

FIG. 123.—ACCUMULATION OF A CONSIDERABLE QUANTITY OF EXUDATION IN THE TYMPANIC CAVITY, IN A MAN WITH A CHRONIC CATARRH OF THE NASO-PHARYNX.

The line of the fluid level is visible only in front of the handle of the malleus. Removal of the exudation by paracentesis of the membrana tympani.

FIG. 124.—FROTHY SECRETION IN THE TYMPANIC CAVITY AFTER INFLATION, IN A CASE OF ACCUMULATION OF SEROUS FLUID IN THE TYMPANIC CAVITY, IN A PATIENT WITH AN ACUTE CATARRH OF THE NASO-PHARYNX.

The curvature of the membrana tympani in acute cases of sero-mucous catarrh seldom shows any noticeable deviation from the normal. On the other hand, in those chronic catarrhs associated with impermeability of the tube, the membrane is forced inwards by the external atmospheric pressure. While the handle of the malleus is retracted inwards and backwards, and thereby appears as if it were shortened, the processus brevis and posterior fold of the membrane project markedly outwards (Figs. 126 and 127). In these cases, the short process of the malleus appears as a prominent, three-cornered, pointed projection, and the posterior fold as a whitish or tendon-gray, sharp ridge. If we study this ridge of the posterior fold more closely, it will be seen to be sometimes straight and sometimes curved downwards and backwards like a bow, forming an acute angle with the handle of the malleus. When the membrana tympani is

excessively retracted, the handle of the malleus appears perspectively shortened owing to its horizontal position, and may be completely hidden by the posterior half of the membrane.

The inward curvature of the membrane is rarely uniform; as the central portion is less resistant than the peripheral portion, the former is more strongly forced inwards by the external air pressure. This produces in the anterior inferior quadrant a curve which the author was the first to describe as the peripheral curve of the membrana tympani, and which is recognized as a linear, lustrous stria (Fig. 125). Besides this lustrous line, a small, irregular or narrow reflection of light is found in front of the umbo. The colour of the membrane in chronic cases is often a dark gray (yellowish-gray if exudation is present); this colour may have a violet or reddish tinge, dependent on the intensity of the redness of the inner tympanic wall.

After the catarrh has lasted a long time, there occurs, more frequently in the posterior than in the anterior half of the membrane, a partial or general atrophy and depression of the membrana tympani. These atrophies may be present without producing any disturbance of hearing. They appear as sharply or ill-defined, irregular depressions, with one or more reflections of light at their lowest part, and bear a great resemblance to the cicatrices of the membrana tympani. In cases of general atrophy, the more or less retracted membrane has a number of linear

Fig. 125.—Appearance of the Membrana Tympani during a Catarrh of the Eustachian Tube and Tympanic Cavity, in a Boy suffering from Great Deafness.

Great inward curvature of the membrane. Cured by inflation after the author's method, which was continued for several weeks.

light reflexes which run in a radiating direction from the periphery towards the handle of the malleus, and which are brought about by the formation of folds in the atrophic membrane. If the atrophied posterior portion is forced inwards to such an extent that it comes into contact with portions of the inner tympanic wall, the long process of the incus and posterior crus of the stapes will be seen behind the handle of the malleus as a bone-yellow, angular, curved protuberance (Fig. 128). If, finally, the membrane is in apposition with the promontory, the latter will be distinguished as a projection having a yellowish lustre, behind which a depression will be seen, which indicates the niche or recess of the fenestra rotunda.

When the membrane is retracted, a striking change takes place in its appearance immediately after inflation. For example, the handle of the malleus returns nearly to its normal position

(Fig. 126), its vessels become greatly injected,* the processus brevis is much less prominent, and the posterior fold of the membrane, which was formerly sharply defined, becomes almost completely obliterated. What is sometimes very striking is that, in consequence of the bulging out of the membrane, the handle of the malleus lies almost invisible in a groove, the *sulcus malleolaris* (Fig. 127). Small, atrophied spots in the membrana tympani curve outwards in a bubble-like manner after an inflation of air, and not infrequently the exudate, forced into them from the tympanic cavity, can be seen as a yellowish mass in their inferior portion. When the atrophied portion of the posterior part of the membrana tympani (Fig. 129) lies in contact with the incudo-stapedial joint and the promontory, they immediately disappear from view after an inflation of air. There will now be

Fig. 126.—Appearance of the Membrana Tympani in a Man 30 Years of Age.

Patient had suffered for two months from a catarrh of the middle ear, with great swelling of the mucous membrane of the Eustachian tube, in consequence of a cold in the head. The membrane was concave, and its colour grayish-violet. The great deafness was cured by inflation after the author's method in three weeks.

Fig. 127.—Condition of the Membrana Tympani in the Same Patient immediately after Inflation.

observed, at the place where these anatomical landmarks were formerly visible—in other words, in the posterior part of the membrane—a grayish-yellow, round or oval bulla (Fig. 129), which either partially or completely arches over the manubrium. Such a bulla is, however, only of short duration, as the atrophied portions sink in again in consequence of the speedy rarefaction of the air in the tympanic cavity.

To the category of catarrhs of the middle ear belongs that group of inflammatory catarrhs in which the sero-mucous exudation is accompanied by more or less marked reactive symptoms.

* By the rapid change in the position of the membrane and manubrium a temporary venous stasis of the vessels of the malleus is brought about, in consequence of the sudden bend of the vessels running from the auditory canal to the membrana tympani.

These affections develop in the course of a catarrh or influenza, and generally begin with lancinating, intermittent pains, and with marked congestion of the vessels of the malleus and of the external auditory canal. This congestion is soon followed by a visible exudate in the tympanic cavity. In this form, which lies between a catarrh and an acute inflammation of the middle ear, the membrana tympani is either protruded as a whole or partially. If the latter is the case, the posterior superior quadrant of the membrane is bulged in the shape of a bulla (Fig. 130). The appearance of the membrana tympani shows great resemblance to the serous bullæ seen in acute myringitis, but is differentiated from the latter by the fact that, in inflammatory catarrh, the protuberance communicates with the tympanic cavity. This communication can be demonstrated as follows: If, after an

Fig. 128.—Appearance of the Membrana Tympani in a Young Man, 17 Years of Age, who had suffered for Eight Years from Chronic Catarrh of the Middle Ear.

Naso-pharyngeal catarrh, with great swelling of the mucous membrane of the Eustachian tube. Hearing distance almost normal after one inflation according to the author's method.

Fig. 129.—Condition of the Membrane in the Same Patient immediately after Inflation.

inflation of air, the protuberance presents two colours—namely, a gray (superiorly) and a yellow (inferiorly)—it is quite evident that there is air and fluid in the bulla. This form of catarrh heals more quickly than the ordinary forms; still, an acute suppurative inflammation of the middle ear may develop from it.

Symptoms.—As a rule, middle-ear catarrhs run their course without pain; only seldom are shooting pains experienced in the beginning of the process and in the inflammatory form (inflammatory hydrops, Zaufal). On the other hand, there is more frequently a sensation of fulness, numbness and pressure in the ear, similar to that experienced when water remains in the ear after a bath. This annoying symptom, which is especially pronounced when the pharyngeal orifice of the Eustachian tube is swollen, is, according to the author's observation, in

inverse proportion to the degree of swelling and impermeability of the tube. To be more explicit, the more trifling the swelling and disturbance of hearing, the greater the sensation of fulness. When the tube is absolutely impermeable, and there is a marked disturbance of hearing, the sensation of fulness is generally wanting. The effort to relieve this sensation by frequently shaking the finger placed in the external auditory canal is very injurious.

An important, though not constant, diagnostic symptom is the sensation as if a body were moving to and fro in the ear when the position of the head is changed. This feeling frequently corresponds with the motion of the exudate seen through the membrana tympani.

FIG. 130.—HEMISPHERICAL BULGING OF THE POSTERIOR SUPERIOR PORTION OF THE MEMBRANA TYMPANI. YELLOWISH EXUDATION IN THE TYMPANIC CAVITY OF A MAN WHO HAD A CATARRHAL DISCHARGE IN THE MIDDLE EAR DURING A COLD IN THE HEAD, WITH SLIGHT INFLAMMATORY SYMPTOMS.

Cured in two weeks by Politzerization.

The subjective noises in the exudative forms of catarrh are not constant, but usually intermittent; they frequently develop suddenly when the disease becomes aggravated, and are accompanied by a rapid decrease in the hearing. Their disappearance takes place just as rapidly, and is due to an improvement in the hearing, which occurs spontaneously, or in consequence of treatment. Often, immediately after an inflation of air, the tinnitus will either become remarkably diminished or entirely disappear in consequence of reduced pressure on the labyrinth. Where tinnitus has lasted a long time, and continues in spite of the restoration of the permeability of the tube through treatment, the prognosis may be said to be unfavourable, as it must then be considered a symptom indicating the development of permanent changes at the windows of the labyrinth, or a labyrinthine disease. The author has nevertheless seen cases in which the catarrh has lasted several months, and in which the continuous subjective noises finally disappeared. He has frequently observed subjective noises in those cases of catarrh of the middle ear due to syphilis of the naso-pharynx. It must be mentioned that in catarrhs a crackling and snapping in the ear are often experienced, which are especially noticeable when swallowing and masticating, and are due to contractions of the muscles of the tube.

One of the most annoying symptoms in catarrhs of the middle ear is the resonance of the patient's own voice (autophonia). This symptom is more noticeable in slight catarrhs and in

unilateral affections than when both ears are diseased. This subjective sensation is often so annoying that the patients avoid conversation of every kind. It is encouraging to know that autophonia often disappears during treatment, and seldom remains for any length of time after a cure of the catarrh has been effected.

In some cases, the only subjective symptoms are a feeling of heaviness and fulness in the head. When these symptoms affect adults, they complain of troublesome pressure in the head, and of the inability to do mental work. In children, these symptoms become manifest by ill-humour, waywardness, disinclination to learn, and weakness of memory (Guye's aprosexia). These mental symptoms usually disappear with surprising rapidity after the repeated application of the author's method of inflation, or after catheterization. The occurrence of delirium, frenzy, and epileptic attacks in simple catarrhs of the middle ear is rare. These symptoms generally disappear after a successful treatment of the middle-ear catarrh.

Disturbances of Hearing.—The disturbances of hearing in exudative catarrhs of the middle ear are brought about by the abnormal tension of the membrana tympani and ossicles, and by the accumulation of secretion in the middle ear. If the secretion is of a thin, fluid nature, there often occurs, when the head is bent forwards, a marked improvement in hearing; if, on the other hand, the head is bent backwards, the hearing distance decreases. This is caused by the flow of the fluid away from and towards the labyrinthine windows. A characteristic feature of this form of catarrh is the marked variation in the hearing distance, which differentiates it from the advanced cases of catarrhal adhesive processes and otosclerosis. The deafness is influenced by a great variety of internal and external causes. As a rule, the hardness of hearing is more marked in autumn and in winter, and on damp and foggy days, than in summer and in dry weather. Every change in temperature and over-indulgence in alcoholic beverages, especially the intercurrence or exacerbation of a naso-pharyngeal catarrh, may produce a sudden aggravation of the disturbances of hearing.

An improvement in the hearing frequently arises quite suddenly, and is accompanied by the sensation of a report in the ear. This symptom is especially observed in those cases in which the tube has been impermeable for a considerable time, and in which the air suddenly enters the tympanic cavity either through a diminution in the swelling or through the removal of a mucous plug in the Eustachian tube. This sudden change in hearing is sometimes accompanied by a transitory, painful hyperæsthesia for noises. In like manner, a sudden diminution in the hearing may arise with the feeling of closure of the ear, or with the feeling as if a wall were placed before it. The power of hearing better

in noises is also observed in this form of catarrh, but to a far less degree, than in otosclerosis.

The perception for the watch and acoumeter through the cranial bones is always preserved, and not infrequently is even more intense. Only in those cases of middle-ear catarrh complicated with labyrinthine syphilis may this perception be lacking; this is less often the case in influenza, typhoid fever, and in other infectious diseases. In cases in which no infectious disease is apparent, the author wishes to attach special importance to this symptom in young individuals, as it has repeatedly led him to suspect syphilis, which was confirmed by a Wassermann examination of the blood. As a rule, in cases of catarrh with a marked disturbance of hearing, the perception for the low range of tones is reduced and the time of perception for all tones through the air is shortened. When performing Weber's test, the tone of the tuning-fork is generally lateralized towards the affected ear, only occasionally towards the better one. Should the case be complicated with labyrinthine syphilis, the tone will generally be lateralized in the normal or better hearing ear. If in cases of slight unilateral catarrh, and furthermore in intumescence of the pharyngeal orifice of the tube, the clinical examination shows nothing else, it is quite certain that the tone of the tuning-fork placed on the vertex will be lateralized in the affected ear. In slight disturbances of hearing, Rinne's test is positive; in deafness of a high degree it is mostly negative, with lengthened perception through the cranial bones (Schwabach). The results of auscultation in exudative middle-ear catarrhs have already been discussed in the general part (p. 119).

Course and Terminations.—Exudative catarrhs of the middle ear generally run a protracted course. The acute simple catarrhs, or those which develop during the course of an acute coryza, heal rapidly, inasmuch as they recede either spontaneously or after a short treatment. One is sometimes able to combat the catarrh after a treatment of a few days; often, however, it requires several weeks. Catarrhs occurring during the course of the acute exanthemata, influenza and typhoid, in lymphatic, anæmic, and cachectic individuals, and during chronic naso-pharyngeal affections, have a protracted course.

The termination of acute catarrhs is either in a prompt cure or there is a transition into the chronic state, more rarely into an acute purulent middle-ear inflammation with perforation of the membrana tympani.

Chronic catarrhs take an uncertain course. The transition of an acute catarrh into the chronic form is especially favoured by the tendency of middle-ear catarrhs to relapse. After the cure of a catarrhal affection, the mucous membrane of the middle ear remains for a long time so sensitive to harmful influences that a slight cold, a cold bath, or a severe coryza, suffices to produce

a return of the exudation in the middle ear. A peculiarity of catarrhs is that every relapse exceeds the former in duration, until finally, after frequent relapses, the affection becomes permanent, and changes are developed in the middle ear which are incapable of complete restitution. Relapses are especially frequent in children who are subject either to hypertrophy of the tonsils or to transient or permanent catarrhs of the naso-pharynx associated with adenoid vegetations. These relapses in children usually appear in the spring and autumn, and particularly in the winter, and generally disappear entirely or partially in the summer, only to recur in the following autumn. In this manner, catarrhs of the middle ear in children may recur regularly until they are fourteen to sixteen years of age, after which the relapses either cease completely or occur more rarely.

Also in adults chronic naso-pharyngeal catarrhs, and the changes in the naso-pharynx produced by them, exercise an important influence on the chronicity, course and termination of the middle-ear affection.

The changes in the Eustachian tube are also of importance in regard to the course of middle-ear catarrhs. Therefore, before going further we must lay stress on the fact that, even after the exudate has been completely removed from the middle ear, and a return of the hearing function to the normal has occurred, a permanent cure cannot be expected as long as the permeability of the tube has not been established. From the foregoing it is evident that, when treating catarrhs of the middle ear, we must first try to make the tube permeable. Cases are nevertheless met with in private practice where, in spite of a lengthy local treatment, no improvement ensues, but where, after a pause in the treatment extending over several weeks or months, a spontaneous cure takes place.

From a prognostic as well as from a therapeutic standpoint, it is important to ascertain the site of the swelling in the tube. While an impermeability of the canal produced by intumescence of the pharyngeal orifice of the tube may disappear spontaneously in a short time, or may be removed by proper treatment, the extensive swellings in the tube brought about by hypertrophy of the naso-pharyngeal mucous membrane require a protracted treatment. According to Hartmann, it may be inferred that there is a swelling at the ostium pharyngeum tubæ if the air, propelled by the author's method, enters the middle ear only under great pressure, whereas, when the catheter is employed, the air freely enters even under the slightest pressure. If, on the other hand, great pressure is also required during catheterization, a diffuse swelling extending over the whole tube may be inferred.

The quality of the exudate has also an important influence on the course of exudative middle-ear catarrhs. Serous secretions are absorbed with much greater rapidity, and are removed much more easily from the tympanic cavity than tough, syrupy, adhesive mucous masses. There can be absolutely no doubt that

the hearing is affected through the stagnation of secretion in the middle ear. The acute middle-ear suppurations which are developed during the course of a chronic catarrh, and which are especially prevalent in children, are undoubtedly often produced by a secondary bacterial infection of the secretion in the middle ear. It must furthermore be mentioned that an exudate which cannot be absorbed may also produce a permanent hyperæmic condition by protracted contact with the mucous membrane; this may lead to cell-growth and to adhesive connective-tissue formation in the middle ear.

The general diseases which have an unfavourable influence on the course and termination of catarrhs are: scrofula, tuberculosis, Bright's disease, anæmia, marasmus, and all exhausting diseases and cachexiæ, by which the nutrition of the general system is lowered. Acute syphilitic catarrh of the middle ear takes a relatively good course, even if combined with syphilitic disease of the labyrinth.

The author wishes to draw attention to the fact that, even in healthy individuals, an adhesive process in the middle ear may sometimes develop even after the catarrh has lasted a short time, especially if there have been frequent relapses. While experience has shown that many catarrhs that have even existed for many years completely subside and remain quiescent for a long time, we find, on the other hand, that even shortly after the commencement of a slight catarrh, changes may develop in the middle ear which permanently impair the hearing.

Diagnosis.—The diagnosis of exudative middle-ear catarrh is made by ocular inspection—in other words, by seeing the secretion in the middle ear shining through the membrana tympani—and from the anomalies in the curvature of the membrana tympani previously mentioned. When the membrana tympani is cloudy, which prevents the secretion in the middle ear from being seen, and when the changes on the drum are not marked, the diagnosis can then be made only by the results of auscultation, the great variation in the hearing distance, and the marked increase in the hearing after the air-douche.

Prognosis.—The prognosis of middle-ear catarrh is good in the acute primary forms, in individuals otherwise healthy, and in those patients whose conditions of life are favourable. It is more favourable when the secretion is serous than when it is mucous, and better when the permeability of the tube is rapidly re-established. A symptom which indicates a good prognosis is a marked increase in the hearing after the tube has been made permeable, or after the removal of the secretion from the middle ear. If we are dealing with a simultaneous affection of the naso-pharynx, the prognosis is more favourable in simple swellings, which are easily cured, than in chronic hypertrophy. The catarrhs localized in the canal of the tube which are not

complicated with obstinate naso-pharyngeal affections offer a relatively good prognosis.

The conditions which induce an exudative catarrh to take an unfavourable course are frequent relapses and a long duration of the catarrh, a slight improvement in the hearing after the tube has been made permeable, diminished or shortened perception through the cranial bones, obstinate forms of empyema of the accessory sinuses of the nose and ozæna, chronic nasal and post-nasal catarrhs, adenoids and hypertrophied tonsils, a restricted action of the muscles of the palate (paralysis of the soft palate, cleft palate), continuous subjective noises, old age, hereditary predisposition, unfavourable atmospheric conditions, the existence of a general disease accompanied by anæmia and cachexia, over-indulgence in alcohol and excessive smoking.

Treatment.—In the treatment of exudative middle-ear catarrhs we should endeavour to re-establish the permeability of the tube, remove the secretion from the tympanic cavity, and diminish the swelling and secretion of the mucous membrane of the middle ear and tube. Besides this, we must take into consideration a simultaneous naso-pharyngeal affection, and the general health of the patient. Among the therapeutic measures which we have at our disposal, we must first mention:

1. Inflations of Air into the Middle Ear.—In the exudative middle-ear catarrhs the air-douche, according to the author's method, achieves the best results. It has proved indispensable in the treatment of catarrhs of the cavum tympani and Eustachian tube, so common in children. As heretofore mentioned, the most marked and permanent improvement in hearing is produced when the method is performed during an act of swallowing. (Concerning the modifications of this method, see p. 130.)

Where the resistance in the Eustachian tube is so great that it cannot be made permeable by Politzerization, we must resort to the catheter. In such cases, the resistance in the tube is diminished to such extent by one application of the air-douche through the catheter that the course of treatment can be successfully continued by the author's method. The air-douche by means of the catheter is contra-indicated if the air penetrates freely into the middle ear during Politzerization. Experience has shown that the repeated contact of the hard beak of the catheter with the diseased mucous membrane of the tube increases the swelling and secretion in the middle ear.

The air-douche brings about a marked improvement in the hearing in the exudative forms of middle-ear catarrh. By means of this simple therapeutic agent the improvement, in the milder forms, lasts some time; while in excessive swelling of the tube, associated with copious and tenacious exudation. the improvement in hearing disappears very rapidly. In the beginning. the increase in the hearing distance usually makes rapid strides,

which becomes less marked as treatment is continued. One should always remember that a constant increase in the hearing distance without a relapse signifies an improvement of the catarrhal process, while the rapid diminution of the hearing should be looked upon as a symptom of continuance of the catarrh or of accumulation of tough mucous secretion in the middle ear.

Inflations of air have a good effect on the head symptoms accompanying catarrhs of the tube and middle ear; they often lessen, with surprising rapidity, the troublesome feeling of pressure, heaviness, and confusion of the head. The effect of the air-douche is most evident in children; not only do the uneasiness, ill-humour, and aprosexia (Guye) disappear, but after a short time the unhealthy appearance and sickly colour also show a decided improvement.

It must be borne in mind that the inflations of air should be continued daily if the greater part of the improvement in the hearing again disappears within twenty-four hours. If, on the other hand, after treatment for several days, a steady increase in the hearing distance is observed, an inflation is repeated every second, and then every third day, and finally, if the improvement continues, only once a week until no fluctuations in the hearing distance are perceptible.

In the acute and chronic catarrhs of children and adults, a cure is obtained much quicker and more often by the systematic application of the author's method than by the use of the catheter. Experience has shown that the use of the air-douche, according to the method of the author, generally suffices without the application of any other local treatment. By the use of Politzerization a cure is obtained much oftener and with greater rapidity than with catheterization—a fact which experience has satisfactorily confirmed.

In all cases in which a middle-ear catarrh is combined with retraction of the drum membrane, rarefaction of the air in the external auditory canal (*vide* p. 135) should be performed immediately after each application of the air-douche. It is well to remember that the effect of the treatment in regard to the improvement in hearing, as well as in diminishing the subjective noises and annoying head symptoms, will be considerably increased by a combination of both methods.

2. **Mechanical Removal of Secretion from the Middle Ear.** —The mechanical removal of secretion from the middle ear is indicated when there is a copious collection of serous fluid, or a tough, mucous secretion in the tympanic cavity.

Serous fluid in the middle ear may be partly or entirely removed in the following manner: If the head of the patient is strongly inclined forwards and to the opposite side while an inflation of air is given according to the author's method, the Eustachian tube is opened up, whereupon the serous or syrupy

exudate will flow into the naso-pharynx. That a diminution in the secretion of the middle ear has taken place may be proved by the fact that the yellow reflex on the drum membrane has disappeared, and that the fluid-line, which was formerly high, has become lower or almost entirely obliterated.

Paracentesis of the membrana tympani or myringotomy for the removal of a serous transudate or mucous masses from the tympanic cavity was already performed by Itard, Busson, Frank, Bonnafont, and Philippeaux, and again introduced into practice by Schwartze. This operation is indicated if, after the inflation of air for several days, no diminution of the secretion is observed, and even if no exudate is demonstrable, the greater part of the improvement in hearing, which takes place immediately after an air-douche, again disappears within a day or two. Besides these two recognized indications for paracentesis, it is also performed in those cases in which, at the first examination, the serous or mucous secretion is seen to be copious; by this means the time of treatment is decidedly shortened.*

Paracentesis of the membrana tympani or myringotomy, a simple, easily performed operation with which every practitioner should be acquainted, is carried out by means of a delicate knife or the double-edged, spear-shaped lancet, as depicted in the accompanying plate (Fig. 131). This should always be thoroughly sterilized before using. The operation consists in making a free incision through the layers of the drum, in order to relieve the pain and tension, and to give free drainage to the fluid in the middle ear. To carry out this procedure, one can resort to a local anæsthetic, but in the majority of cases a slight general anæsthesia is advisable. For local anæsthesia, one can use a pledget

FIG. 131.—LANCET WITH ADAPTABLE HANDLE.

of cotton saturated with Bonaine's mixture, consisting of cocaine, carbolic acid, and menthol, which is placed against the drum and allowed to remain there from ten to fifteen minutes, or one may use the injection method of Neumann as described on p. 487. In most cases, however, it is advisable to give a slight general anæsthesia in the form of ethyl chloride or nitrous oxide.

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* *Diagnose und Therapie der Ansammlung seröser Flüssigkeit in der Trommel-höhle. Wien. med. Wochenschrift*, 1867, and *Ueber bewegliche Exsudate in der Trommelhöhle. Med. Presse*, 1869.

The most suitable site for the incision into the membrane is its posterior inferior quadrant, as this place is easily accessible and is further removed from the inner tympanic wall than the portion of the membrane situated immediately behind the umbo. If the anterior wall of the external meatus is only slightly curved, the anterior inferior quadrant (Figs. 132 and 133) may be chosen for the seat of operation. Should the membrane be strongly bulged, the incision is made at the most prominent part. The direction of the incision has no influence on the duration of cicatrization. Bing recommends, for those who have little experience, the use of the horizontal incision, as the walls of the meatus are not so easily injured as in making a vertical one. In order to keep the incision open a long time, Jansen forms a flap by means of a semicircular incision at the posterior periphery of the membrane.

FIG. 132.—VERTICAL INCISION IN FRONT OF AND BELOW THE HANDLE OF THE MALLEUS.

FIG. 133.—HORIZONTAL INCISION IN THE ANTERIOR INFERIOR QUADRANT.

The operation is performed in the following manner: The head of the patient is fixed by an assistant, a speculum as wide and short as possible is inserted into the meatus, and the membrana tympani illuminated with reflected light by means of the head mirror. While the speculum is fixed in the auditory canal with the thumb and forefinger of the left hand, and the light well focussed on that part of the membrane at which the incision is to be made, the instrument, held in the right hand, is introduced as far as the membrana tympani and its layers gently incised. It is far better to make the incision too large than too small, as tenacious masses of mucus will either not pass through a small opening or will do so only with difficulty. The operation, which is, as a rule, very painful, may be performed rather quickly in children and in some tolerant patients without an anæsthetic; in the majority of cases, however, a mild general anæsthesia is advisable. Stress must be laid on the fact that the operation must not be performed over-hastily, as by the rapid introduction of the instrument the walls of the meatus may be incised instead of the membrana tympani. No evil effects are caused by injuring the mucous membrane of the promontory unless the oval or round

windows should be accidentally pierced. Injury to the bulbus venæ jugularis, which has been observed only in a few cases when there has been a dehiscence in the floor of the cavum tympani (Ludewig, Hildebrandt, Gruber, Seligman, Max), runs a favourable course after quickly tamponing. The case reported by Brieger, which ended in death through pyæmia, must be set down as an isolated one. Where a bulging of the bulbus venæ jugularis towards the tympanum is suspected by inspection (*vide* p. 97), the horizontal incision should, according to Gomperz, always be made above the blue transparency.

Immediately after paracentesis one sees, in the somewhat gaping incision, a weak pulsation, or a distinct motion of the fluid. A small drop of fluid sometimes exudes through the orifice to the external surface of the membrane; frequently, however, if the secretion is serous, several bubbles will be seen rising up behind the membrana tympani during an act of swallowing; these bubbles are caused by air entering the tympanic cavity through the perforation. Sometimes an objective, crackling noise is heard during deglutition; this is caused by the gaping of the margins of the wound.

Paracentesis having been performed, we next direct our attention to the removal of the secretion in the tympanic cavity. This is accomplished by a forcible inflation of air, according to the method of the author, immediately after the operation. The writer must lay stress on the fact that it is only by this means that the full effect of the operation is brought about. It is only when there is marked swelling of the tube, and, furthermore, in cases of paresis and paralysis of the muscle of the soft palate and tube, that it is necessary to inject air through the catheter into the tympanic cavity. In exceptional cases, the secretion is forced into the auditory canal more easily by the Valsalva method than by Politzerization or by catheterization.

To remove the secretion completely from the tympanic cavity, it is necessary to repeat the inflation three or four times in succession. If thin fluid secretion is present, the air passes into the external meatus with a marked rattling noise. If the mucous masses are tenacious, either no noise at all, or a grating sound, will be heard. Should the secretion happen to be tough mucus, the membrana tympani will be found covered either with a frothy fluid, or with a yellow or colourless mass. If there is only a small quantity of tenacious mucus, the air passes through the perforation without forcing any secretion into the meatus. If, on the other hand, there is a large quantity of mucous secretion, and especially if the incision in the membrana tympani is too small, the mucus is jammed into the orifice of the perforation and appears as a yellowish-green pearl on the membrane.

In order thoroughly to remove the secretion from the tympanic cavity, the author employs, besides inflations, repeated rarefac-

tion of the air in the external auditory canal (p. 135). During this manipulation the patient is directed to bend the head strongly forwards, so that the secretion can also be aspirated from the mastoid antrum and cells into the external meatus. Rarefaction is also carried out with good effect when catheterization cannot be performed in consequence of malformations of the naso-pharynx, or when the tube is closed by strictures or adhesions. The author has often succeeded in removing the secretion from the middle ear more thoroughly if the air in the auditory canal was first repeatedly condensed and then rarefied. If this means is also unsuccessful in removing tenacious secretion from the cavum tympani, it is advisable to propel it through the tube into the naso-pharynx by forcibly compressing the air in the external meatus. If a mucous plug becomes jammed in a paracentesis opening which is too small, the incision must be enlarged.

When the exudate is of a thin, fluid nature, a part flows off through the external auditory orifice if the head is inclined to the same side; not infrequently, however, a part of the serous secretion is again aspirated into the tympanic cavity. To prevent this, the author pushes a small sterilized pledget of cotton in front of the perforation before giving the second or third inflation of air, by which means the ejected fluid is absorbed. Tenacious mucus may be removed by strongly forcing air into the external auditory canal by repeated inflations. Owing to the danger of infection, syringing the meatus should be avoided.

Before the air-douche is used, a striking improvement in the hearing takes place immediately after paracentesis, because the tension on the membrana tympani has been relieved; this improvement even increases after the removal of the secretion from the tympanic cavity.

The union of the margins of the incision takes place within twenty-four hours, sometimes after 2 to 3 days. Occasionally a serous or syrupy exudation, lasting several days, follows the operation. Consecutive inflammation of the membrana tympani and of the mucous membrane of the middle ear has been observed by Schwartze in 25 per cent. and by Christineck in 41 per cent. of the cases. In the cases operated on by the author such a complication has rarely been seen (1 : 300), and he attributed these good results to the fact that he avoided syringing and irrigating the middle ear.

After paracentesis, the external auditory orifice must be kept closed for twenty-four hours with sterile cotton or with a strip of sterilized gauze.

Hyperæmia, ecchymosis and cloudiness of the membrane, which are seen after paracentesis, entirely disappear within a short time; only rarely does a cicatricial depression or a partial atrophy of membrane remain at the spot where paracentesis was performed.

As regards the curative effect of paracentesis, it may be stated that a complete cure ensues after one operation in more than one-third of the cases. These are mostly cases of acute catarrhs in which the exudative process had already ceased before the operation, and in which the hardness of hearing was caused only by the mechanical action of the exudate.

On the other hand, if there is a simultaneous impermeability of the tube, paracentesis is without lasting effect, as the exudation in the middle ear still continues. Therefore, another accumulation of secretion in the tympanic cavity quickly takes place, which makes it necessary to repeat the paracentesis. When a collection of fluid results in consequence of atresia of the tube and facial paralysis, paracentesis, on account of its temporary effect alone, must sometimes be repeated at intervals for years.

To prevent the accumulation of new secretion after paracentesis, the tube must be kept permeable by means of inflations of air. Accordingly, it is necessary to continue the air-douche for several weeks or months, at first two or three times a week, and later once every eight or fourteen days, until a complete cure is established.

The disturbances of hearing remaining after removal of the secretion are caused either by a continuance of the swelling of the mucous membrane of the tube and middle ear, by anomalies of tension of the membrana tympani, or by lasting tissue changes; the latter very often lead to connective-tissue adhesions, and to rigidity of the articulations of the ossicles even in the secretory stage of the catarrh. Swelling of the tube is diagnosed by auscultation during catheterization, or by means of a bougie. That the deafness is due to anomalies of tension in the sound-conducting apparatus may be inferred, if, in spite of the fact that the tube is permeable, and there is no more secretion in the middle ear, a marked improvement in the hearing occurs after the use of the air-douche, which disappears again when the membrane returns to its former position. Finally, the existence of adhesive changes may with probability be assumed if after the removal of the secretion, as well as after repeated inflations, no material improvement in the hearing results. If, besides this, there are continual subjective noises, which are not relieved by paracentesis, there can be but little doubt that in such cases we are dealing with changes in the recesses of the fenestræ of the labyrinth.

The swelling of the mucous membrane of the tube remaining after the secretion is removed subsides either spontaneously, or after the repeated use of the air-douche. Only when the duration of the catarrh is protracted and obstinate, should medicated applications be made to the swollen tubal mucous membrane. The injection of medicated solutions into the cavum tympani is of little value in the exudative forms of catarrh, especially when

secretion is still present; even if the latter should not be the case, experience has shown that the process often becomes decidedly worse after the use of intratympanic injections. On the other hand, in obstinate swelling of the tube, local medicated applications are often very beneficial. Should we desire to introduce a medicated solution into the tube without allowing it to enter the tympanic cavity, the following procedure will be found of value: An air-douche having been first administered, 8-10 drops of the solution are injected into the catheter with a Pravaz syringe; the head of the patient is now bent to the side and a little backwards, by which means the fluid flows from the catheter into the tube. Another method of introducing medicaments into the tube is by the use of Yankauer's applicators. These are made of delicate wire, at the end of which a small quantity of cotton can be securely fastened. This is moistened with the desired medicated solution, introduced into the catheter and gently pushed into the tube. By this means the solution is directly applied to the affected parts. For this purpose we may use concentrated solutions of zinc sulphate (0·2 : 10), Burow's solution (1 : 5), weak solutions of tannic acid (1-2 per cent.), or a few drops (5-10) of sterilized liquid vaseline (Delstanche). The author has found the latter, combined with zinc olein (0·3 : 30·0), beneficial in marked swelling of the tube. In obstinate cases astringents are sometimes successful only when preceded by several injections of an ammonium chloride (1 : 10-20) or soda bicarbonate (3 : 10-20) solution. Steam, with compound tincture of benzoin and ammonium chloride vapour, as especially recommended by v. Tröltsch and Bürkner, sometimes aid in reducing the swelling of the tubal mucous membrane. Turpentine vapour (oleum terebin.), aspirated from the vial by means of an air-bag and forced through the catheter into the middle ear, has proved beneficial. In cases in which there is a marked accumulation of mucous secretion in the Eustachian tube, the author aspirates the mucus with an air-bag inserted into the free end of the catheter before using the air-douche and injections.

The application of medicated fluids to the mucous membrane of the tube is most effective if alternated with the air-douche by means of the author's method, or by the catheter (on one day the injection, the next the air-douche). As a rule an improvement in hearing is noticeable only from such a treatment. In those cases in which injections of fluids have a bad effect, one must return to the sole use of the air-douche.

The introduction of medicated bougies is recommended in cases of obstinate swelling of the tubal mucous membrane in which air can be forced into the middle ear only with difficulty. The author most frequently employs catgut bougies (thinnest violin strings), which are impregnated with a concentrated solution of silver nitrate; these are dried and pushed through the catheter

as far as the isthmus tubæ, where they are allowed to remain three to five minutes. Often after the third or fourth introduction of these bougies (every 2–3 days) air can be forced through the Eustachian tube by Politzerization. In order to avoid any reactive inflammation of the middle ear, it is well to remember that these bougies, soaked in silver solution, must not be allowed to remain in the tube too long.

Besides the above-mentioned remedies, energetic sweat cures in the form of vapour baths are occasionally very beneficial.

Obstinate catarrhs of the tube and cavum tympani which resist all local treatment often completely subside if the patient changes his place of abode and lives under more favourable atmospheric conditions.

(*b*) The Catarrhal Adhesive Processes in the Middle Ear.

(Syn. : Chronic Middle-Ear Catarrh.—Otitis Media Catarrhalis Chronica.)

Attention has already been called to the fact that it is impossible to draw a sharp line of demarcation between the exudative catarrhs of the middle ear and the adhesive processes developed from them. The reason for this is that the tissue-changes, which lead to permanent disturbances in hearing, often become fully developed during the exudative stage of the catarrh, and that in some forms, exudation and the formation of new connective tissue take place almost simultaneously.

Hence it follows that in the group of adhesive processes of the middle ear about to be described, a great many forms of middle-ear diseases, which show great variations in their anatomical as well as in their clinical aspect, have been brought together.

Pathological Changes.—The pathological changes in the catarrhal adhesive processes either extend over the whole mucous membrane of the middle ear, or are limited to circumscribed areas.

The structural changes in the mucous membrane consist of an increase in substance caused by round-celled infiltration, and in partial or total transformation of the new-formed round cells into fibrous connective tissue. The new-formed connective tissue may remain as such, or lead to fixation of the ossicles through contraction, calcification or ossification.

In cases in which the new formation of connective tissue and exudation co-exist, the hyperæmic, unevenly tumefied mucous membrane appears yellowish or bluish-red, infiltrated with serum, gelatinous, spongy, easily movable, and its surface uneven, glandular or nodular. In consequence of this excessive proliferation of the mucous membrane, the depressions in the tympanic cavity, especially the recesses of the fenestræ ovalis and rotunda and the attic, are filled with succulent connective tissue, which is partially of new formation, and which completely envelops the stapes and the malleo-incudal body. At times the mastoid antrum and cells are filled with the same œdematous connective tissue. When the tympanic cavity is filled with tissue of this nature, the mobility of the ossicles is diminished, and the malleo-incudal articulation is often ankylosed. The increase in thickness of the mucous membrane is caused partly by proliferation of round cells and swelling

of the substantia propria, and partly by the new formation of fibrous connective tissue. Through fatty degeneration of the round cells, a partial repair of the diseased mucous membrane can still take place.

In other cases in which exudation has totally ceased, and in which a complete transformation of the new-formed tissue into fibrous connective tissue has taken place, we generally find the mucous membrane smooth, several times as thick as usual, pale, of a dull, tendon-gray colour, rigid, firmly united with the underlying structures, and slightly movable. The thickening and rigidity are not only found in the lining membrane of the tympanic cavity, but also in the folds of mucous membrane and ligaments which extend to the ossicles, as well as in the covering of the capsular ligaments. This thickening is generally most marked where the ossicles come into contact with the walls of the tympanic cavity. Only rarely does partial calcification or the formation of bone (Wendt) occur in the mucous membrane. Whether the changes in the middle-ear mucous membrane mentioned here develop in consequence of a chronic interstitial inflammation without previous exudation has not yet been proved clinically and anatomically.

In still another series of cases we find the tympanic cavity traversed by numerous membranous striæ and bands, which often cross each other, and by which the membrana tympani, the ossicles, and the tensor tendon are abnormally united with each other and with the walls of the tympanum. They divide the cavum tympani into two or more cavities (Fig. 134). These striæ develop less often as primary pathological formations,[*] but must be regarded (as the author has shown on a large series of specimens[†]) as thickened bands and folds, due to the catarrhal middle-ear process, which are so often met with in the normal ear as the residue of the fœtal mucous membrane cushion (Fig. 134). These striæ, which are formed from normal mucous membrane folds, as well as from pathological processes in the middle ear, are sometimes transformed into osseous trabeculæ by the deposit of lime salts and by the incrustation of star-shaped corpuscles (de Rossi, Toynbee, v. Tröltsch). We further find localized or extensive adhesions between the membrana tympani and the inner wall of the tympanic cavity, and sometimes a partial or complete obliteration of the attic, or of the whole cavum tympani. This is caused by the transformation of the excessively proliferated mucous membrane into fibrous connective tissue, and by its complete union with the inner layer of the membrana tympani (mucosa) and with the covering of the ossicles. The author once found in the newly-formed connective tissue in the attic, isolated accumulations of adipose tissue.

Through the changes in the tympanic cavity described above, the power of vibration of the sound-conducting apparatus is more or less impaired. The main factors in producing this impaired conduction are due to the adhesion of the ossicles to the walls of the tympanic cavity, and to ankylosis of the ossicular joints. The adhesions are brought about by the formation of tense fibrous (*ankylosis membranacea s. spuria*) or osseous tissue (*ankylosis ossea s. vera*, Frey). The ankylosis affects either all the ossicles, or any one of them may be separately united with the walls of the tympanic cavity. Accordingly, we find an ankylosis between the head of the malleus alone or together with the body of the incus, with the tegmen tympani, or there may be an adhesion between either of these two ossicles and the external wall of the tympanic cavity. In cases of congenital deafness the author has often found the long process of the incus and the stapes adherent to the posterior wall of the cavum tympani.

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* Clarence J. Blake: 'Reduplications of Mucous Membrane in the Normal Tympanic Cavity: their Clinical Importance' (*Archives of Otology*, vol. xix., 4, 1890).

† Politzer, *Sur les changements anatomiques des processus adhésifs de l'oreille moyenne et leur diagnostic. Congrès internat. de Médecine*, Madrid, 1903.

A connective-tissue or osseous attachment of the crura of the stapes with the fenestra ovalis is the most unfavourable termination of a catarrhal adhesive process of the middle ear. It affects either the stapes alone, or is combined with ankylosis of the malleus and incus, with adhesions between the membrana tympani, ossicles, and inner wall of the tympanic cavity, with the formation of striæ and bridges in that cavity, and with thickening and calcification of the membrane of the fenestra rotunda.

According to the author's observations, ankylosis of the crura of the stapes takes place most frequently with the inferior wall of the recess of the oval window (Fig. 135), more rarely with the anterior or posterior walls (Fig. 136)
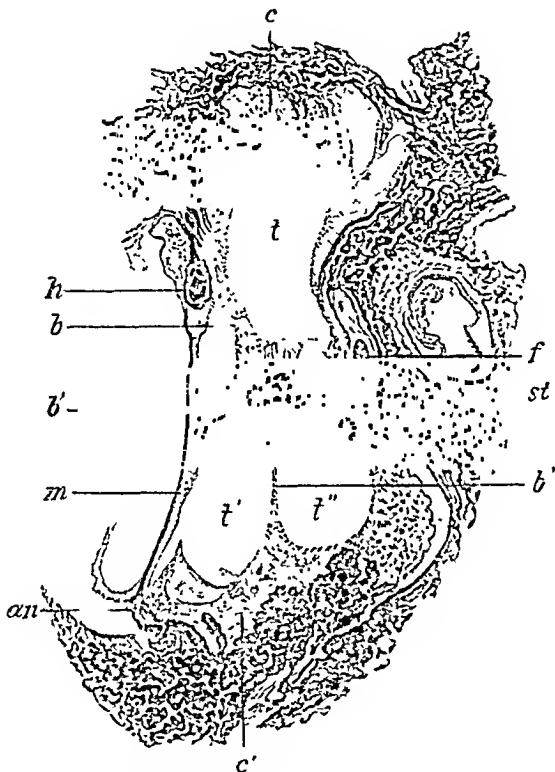
FIG. 134.—SECTION THROUGH THE TYMPANIC CAVITY OF A DEAF MAN.

h, Handle of the malleus; *m,* Tympanic membrane; *an,* Annulus tendinosus; *st,* Head of the stapes; *f,* Facial nerve; *b, b', b",* Newly formed connective-tissue bridges in the tympanic cavity; *t, t', t",* Spaces in the tympanic cavity formed by these membranous bands. (From a specimen in the author's collection.)

In an individual said to have been congenitally deaf, the crura and head of the stapes were found to be united with the superior wall of the recess.

Ankylosis of the stapes is predisposed by congenital narrowing of the recess of the fenestra ovalis, and by the presence of those thread and band-like filaments which are not infrequently found in great numbers in the cavum tympani and in the above-mentioned recess. As heretofore stated, these bands are the remains of the fœtal mucous membrane cushion; cases have even been observed in which the crura of the stapes have been enveloped by the striæ in the form of a thick network (Fig. 137). Even in those cases in which these filaments and bridges of mucous membrane appear to be absent, one finds on closer examination a few bridges of mucous membrane connecting

tho crura of the stapes with the walls of the recess (Gradenigo).   The nearer
the crura of the stapes lie to the walls of the recess in the normal state, the
more easily will inflammation produce ankylosis of these parts (Politzer,
Gradenigo).*

The pathological changes in the fenestra cochleæ (rotunda) are not less
important.   In normal cases one also finds here threads or a fibrous frame-
work stretched across the recess which leads to the membrane of the round
window.   In cases of chronic catarrh these bands form the basis of the con-
nective-tissue masses which fill the recess of the round window.   Besides
this, the author has frequently found the membrane closing in the round
window thickened (Fig. 138) and covered with a villous growth, and the recess
itself greatly narrowed or completely closed.   In two cases, the recesses of
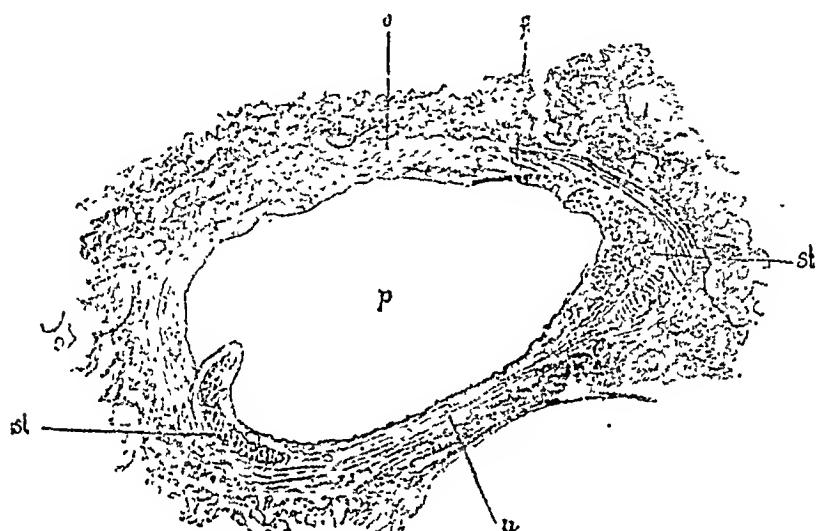
Fig. 135.—Adhesion of the Crura of the Stapes with the Lower Wall
    of the Pelvis Ovalis, from the Left Ear of a Woman, aged 48 Years,
    who gradually grew Deaf, and who died in the Almshouse.   The
    Impairment of Hearing dating Twenty Years back in the Left, and
    Ten in the Right Ear.   Microscopical Section through the Pelvis
    Ovalis and the Crura of the Stapes.

p, Pelvis ovalis; *o*, Upper wall of the niche; *n*, Mucous membrane of the lower
    wall of the niche, which has been changed into fibrous connective tissue;
    st, *st*, Sections of the crura of the stapes covered with tough fibrous connective
    tissue.   (From a specimen in the author's collection.)

both fenestræ were filled with adipose tissue.   Calcification and ossification of
the membrane of the fenestra rotunda were observed by Toynbee and v. Tröltsch
in a few cases.

Besides the changes in the stapedio-vestibular articulation, one occasionally
finds changes in the other articulations of the ossicles in the adhesive processes
of the middle ear.   Of these may be mentioned thickening of the mucous
membrane covering the malleo-incudal articulation and ankylosis of the joint
itself (Toynbee, Zaufal, v. Tröltsch, Hugo Frey).   In ankylosis of this joint
the author proved histologically that the cartilaginous articular surfaces, in-
crusted with lime salts, are adherent to the meniscus and to each other.
Ankylosis of the stapedio-incudal articulation was found by Toynbee only
twice among 1,149 specimens.

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* Congrès Otologique, Brussels, 1888.

What influence do the catarrhs of the middle ear have on the pathological changes in the Eustachian tube? Experience has shown that the diffuse form, especially if combined with chronic naso-pharyngeal affections, may lead, through hypertrophy of the tubal mucous membrane and through

FIG. 136.—HORIZONTAL SECTION THROUGH THE NICHE OF THE FENESTRA OVALIS AND STAPES OF A MAN, AGED 77, WHO WAS NEARLY DEAF. ADHESION OF THE POSTERIOR CRUS OF THE STAPES WITH THE CORRESPONDING WALL OF THE NICHE.

p, Base of the stapes; *st*, Head of stapes; *a, a'*, Stapedio-vestibular articulation; *v*, Adherence of the posterior crus of the stapes with the wall of the niche. (From a specimen in the author's collection.)

shrinking of the submucous connective tissue, to slight or marked strictures of the tube. Kirchner found in one case the formation of diverticula on the floor of the Eustachian tube. The author has several times found the mucous
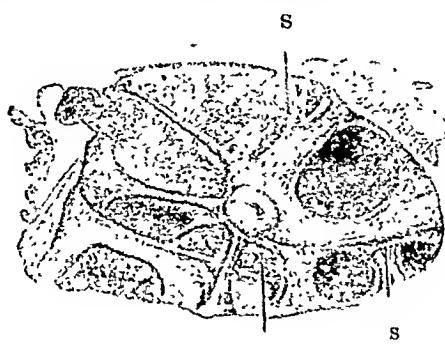
FIG. 137.—NICHE OF THE FENESTRA OVALIS, WITH THE CRURA OF THE STAPES IN THE NORMAL EAR OF AN ADULT. NETWORK OF BANDS EXTENDING FROM THE CRURA OF THE STAPES TO THE WALLS OF THE NICHE.

c, Head of the stapes; *ss*, Crura of the stapes.

membrane covered with stratified cylindrical or pavement epithelium, which was infiltrated with fat globules, and, furthermore, the submucous connective tissue thickened, the glandular layer hypertrophied in some places, atrophied in others, and once completely lacking. He has further observed that in some

cases the mucous membrane was glandular, papillary, or smooth, and the cartilage infiltrated with fat globules and pigment.

The changes in the muscles of the Eustachian tube are of importance, because by their decreased power of action the ventilation of the middle ear, necessary for the function of hearing, is greatly impaired. Besides the paralytic conditions, due to diphtheria and facial paralysis, we must mention fatty degeneration of the muscular apparatus of the pharyngeal portion of the tube met with in old persons and in cases of long-standing catarrh of the naso-pharynx. One also sees atrophy and cicatricial contraction of the muscles in consequence of ulceration (syphilis, scrofula) of the naso-pharyngeal mucous membrane, as well as restricted action of the muscles in defects of the palate, in cleft palate, and in adhesions of the velum palati to the walls of the pharynx.

The pathological changes in the intratympanic muscles consist of fatty degeneration, atrophy, and cicatricial or colloid degeneration (Moos). These are caused partly by inflammation of the mucous membrane of the middle ear near these muscles, and partly by their non-use in consequence of ankylosis

FIG. 138.—ANTERIOR SECTION THROUGH THE NICHE OF THE FENESTRA ROTUNDA IN A WOMAN AGED 80 YEARS. THICKENING AND HYPERTROPHY OF THE MUCOUS MEMBRANE COVERING THE FENESTRA ROTUNDA FOLLOWING MIDDLE-EAR CATARRH.

pr. Promontory; *r, r′*, Membrana fenestræ rotundæ; *e,* Hypertrophic mucous membrane covering the membrana fenestræ rotundæ. (From a specimen in the author's collection.)

of the ossicles with the walls of the tympanum. In spite of the fact that these degenerative changes are generally attributed to the arrested action of the muscles, the author could nevertheless often find no changes in the intrinsic muscles of the ear even in a long-standing ankylosis of the stapes.

That, in catarrhal adhesive processes, analogous changes may develop in the labyrinthine capsule just as in the typical forms of otosclerosis, has been proved anatomically (mixed forms) by the author in his article ' On Primary Disease of the Labyrinthine Capsule ' (*Zeitschrift für Ohrenheilkunde*, vol. xxv.). The pathological changes in the labyrinth which are associated with these middle-ear processes will be referred to in the chapter dealing with this subject.

Of the changes in the labyrinth and auditory nerve which accompany chronic catarrhal adhesive processes, and which will again be referred to later, we must mention amyloid degeneration of the terminal filaments of the acoustic nerve (Voltolini), and the deposit of pigment in the cochlea.

Etiology and Occurrence.—The most frequent causes which favour the development of a catarrhal adhesive process from a middle-ear catarrh are:

(1) Frequent relapses of an exudative middle-ear catarrh. (2) Chronic affections of the naso-pharynx and ozæna which keep up the middle-ear catarrh. (3) Paresis and paralysis of the muscles of the palate and tube owing to a paralysis of the facial nerve after diphtheria; furthermore, fatty degeneration and atrophy of these muscles by which the ventilation necessary for the function of hearing is impaired.* (4) General diseases, especially a lymphatic diathesis, tuberculosis, syphilis, Bright's disease, chronic rheumatism, anæmia, and marasmus. (5) Pregnancy and the puerperal state. (6) Hereditary predisposition.

FIG. 139.—SEMILUNAR OPACITY BEHIND THE HANDLE OF THE MALLEUS IN A WOMAN 38 YEARS OLD.

Duration of the ear disease six years; greatly aggravated during the last three. Acoumeter = 1 cm. Speech = 10 cm. Perception through the bones of the skull unaltered. The tuning-fork placed on vertex was heard best in the affected ear.

FIG. 140.—SEMILUNAR CHALKY DEPOSIT IN FRONT OF THE HANDLE OF THE MALLEUS IN A MAN 38 YEARS OLD

(7) External injurious influences, such as frequent colds, a long sojourn in a cold, moist climate, unfavourable occupation and poor hygienic surroundings. (8) The over-indulgence in alcoholic beverages and the excessive use of tobacco.

Catarrhal adhesive processes in the middle ear occur most frequently in middle-aged and old people, less frequently in children and young persons. The latter, however, are most subject to the exudative forms of catarrh. The catarrhal adhesive processes which develop during childhood are due to general disturbances of nutrition, especially to a lymphatic diathesis, hereditary syphilis, anæmia, or to hereditary predisposition. In the constitutional diseases of childhood mentioned here, the danger that the catarrh will become chronic is increased owing to the frequency of naso-pharyngeal catarrhs. The fact must

* According to Royet, the adhesion of the Eustachian tube with the posterior pharyngeal wall is a frequent cause of adhesive changes in the tympanic cavity.

not be lost sight of that the adhesive processes in the middle-aged are frequently caused by catarrhs which date from childhood.

The disease usually occurs in both ears; it is rare to find it confined to one ear during the entire life of the patient. When the affection is bilateral, it usually presents the same character in both ears. Sometimes the symptoms of an exudative catarrh are well marked in one ear, while an adhesive process exists in the other.

Condition of the Membrana Tympani.—The most important changes on the drum membrane which warrant the diagnosis of a catarrhal adhesive process in the middle ear are opacities and retractions. The opacities are either circumscribed or take in the entire membrane. The circumscribed or partial opacities have a tendon-gray colour, are striated or spotted, and sharp- or ill-defined, between which the normal or partially opaque portions of the drum membrane appear as dark spots apparently deeper. These opacities vary greatly in size and shape. A very common opacity is the semilunar, which is situated behind the manubrium; its margins are ill-defined, and its colour is tendon-gray, or similar to milk-white glass (Fig. 140). Peripheral, whitish-gray and circular opacities are found just as frequently; they may be compared to the arcus senilis of the cornea, and are due to the thickening of the mucous membrane of the periphery of the membrana tympani and to opacity of the annulus tendinosus. Calcareous deposits on the membrana tympani are less frequently observed. When they do occur they appear as chalky-white, sharply defined spots,

FIG. 141.—HORSESHOE SHAPED CHALKY DEPOSIT IN THE MEMBRANA TYMPANI OF A WOMAN 30 YEARS OLD.

Duration of the ear disease ten years. Tinnitus seldom. Acoumeter = 30 cm. Speech = 3 m.

situated between the handle of the malleus and the periphery of the membrane. They are found most frequently in front of the handle of the malleus, more rarely behind it, in the shape of crescents with their convex margins directed towards the periphery (Fig. 140). Sometimes accumulations of chalk are situated both in front of and behind the handle, or the inferior extremity of the manubrium is surrounded by a horseshoe-shaped deposit (Fig. 141).

When the membrana tympani is entirely clouded, it appears either of a homogeneous, bluish-white colour, like a glass surface that has been breathed upon, or irregularly spotted gray; it may furthermore have the appearance of a non-transparent, saturated, whitish-gray membrane, resembling frosted glass, upon which the posterior fold of the membrana tympani is plainly marked. When the membrana tympani is greatly

thickened, or when it is united with the inner wall of the tympanic cavity, it presents the appearance of a yellowish disc of parchment. In those cases in which the connective tissue in the cavum tympani causing this adhesion is very hyperæmic, the membrana tympani has a reddish- or bluish-gray appearance. The handle of the malleus is often ill-defined, apparently widened, and at times reddened by injection of its vessels; the umbonic opacity is enlarged; the light reflex is either normal or irregularly ill-defined, and when the membrana tympani is retracted, appears markedly narrowed and lengthened or at times shortened or entirely lacking.

Besides the above changes, the curvature of the membrane presents marked alterations. It appears to a greater or less extent strongly drawn inwards, the handle of the malleus fore-

FIG. 142. — RETRACTION OF THE MEMBRANA TYMPANI, FORESHORTENING OF THE HANDLE OF THE HAMMER, SEMICIRCULAR PROMINENCE OF THE POSTERIOR FOLD. FROM A WOMAN WHO HAD CHRONIC MIDDLE-EAR CATARRH FOR SEVEN YEARS.

Acoumeter = 4 cm. Speech = 1 m. Rinne negative.
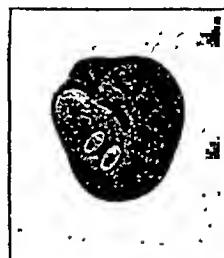
FIG. 143.—CIRCUMSCRIBED DEPRESSIONS IN THE ANTERIOR INFERIOR QUADRANT OF THE LEFT MEMBRANA TYMPANI OF A SCROFULOUS GIRL, 12 YEARS OF AGE. THE ALTERATIONS OF THE MEMBRANE HAD BEEN DEVELOPING FOR SEVERAL YEARS WHILE UNDER OBSERVATION.

shortened, displaced inwards, backwards and upwards, and partly covered by the posterior segment of the membrane; furthermore, the short process and the fold of membrane (Fig. 142), extending straight backwards or bow-shaped downwards from it (posterior fold), are very prominent.* Two short folds often extend from the processus brevis to the Rivinian segment and enclose Shrapnell's membrane, which is either retracted or united with the neck of the hammer and the visible superior surface of the short process. The membrana tympani is either thickened or atrophic, presenting many linear reflections of light which run in a radiating direction.

In addition, circumscribed retracted portions, similar to scars

* Bing was the first to observe that, in rare cases, a second fold is seen underneath the posterior fold of the membrana tympani, extending from the middle of the manubrium towards the posterior margin of the membrane.

on the membrana tympani, are not infrequently observed, which are caused either by partial atrophy (Fig. 143), or by ligamentous or direct union of the membrana tympani to the inner wall of the tympanic cavity (Fig. 144). They appear either as round or oval depressions, surrounded by opaque or thickened portions of the drum membrane (Fig. 143), or as extensive depressions situated mainly behind the handle of the malleus; when the latter is the case, the atrophied part comes into contact with the inner wall of the tympanum, so that the articulation of the incus and stapes becomes visible. When Shrapnell's membrane is adherent to the neck of the malleus, one sees above the processus brevis a marked depression, in which the outline of the neck
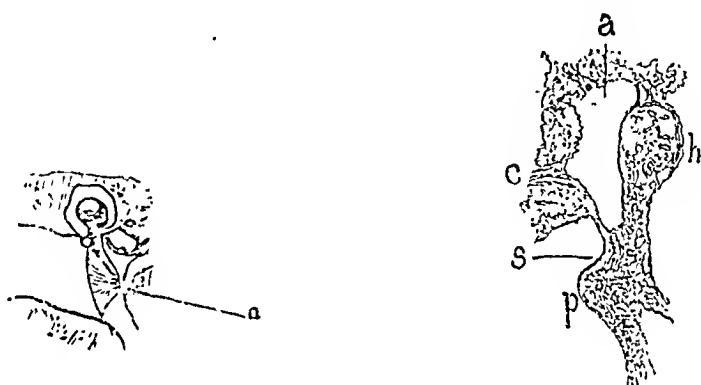
Fig. 144.—Circumscribed Adhesion of the Membrana Tympani to the Promontory underneath the Handle of the Malleus.

a, Place of adhesion on the promontory. (From a specimen of the author's now in the Mütter Museum in Philadelphia.)

Fig. 145.—Section through the Malleus and the External Attic of the Cavum Tympani.

h, The head of the malleus; p, Processus brevis; a, External attic; s, Membrana Shrapnelli adherent to the neck of the malleus; c, Vascular canal leading from the external attic into the meatus. (From a specimen in the author's collection.)

can be plainly seen (Fig. 145). If Shrapnell's membrane is immovable when examining with the pneumatic speculum, it may be assumed that it is adherent to the neck of the hammer. One sometimes finds atrophic spots bulging outwards in the posterior superior quadrant of the membrana tympani (Politzer, Gomperz).

Subjective Symptoms.—Subjective noises in this form of middle-ear disease are much more frequent than in the exudative catarrhs. The noises are intermittent, often, however, continuous. When they are continuous, it may be assumed with probability that the labyrinth is coincidently affected. The noises become very annoying in bad weather, after indulgence in alcoholic beverages, when the patient is affected with a severe coryza, after excessive mental work or nervous excitement,

after great fatigue and bodily indisposition, during pregnancy, etc. Sometimes these paroxysms of subjective noises spread over the whole head. It is a remarkable fact that children rarely complain of subjective noises. In cases in which, after the air-douche or after rarefaction of the air in the external meatus, the subjective noises either cease or become less intense, it may be assumed that this is caused by a decrease in the pressure of the labyrinth, produced by the adhesive process.

Pain in the ear in the adhesive processes is, on the whole, seldom observed; it is either of a neuralgic nature or secondary to a reactive, intercurrent inflammation. In the latter case, hyperæmia and inflammatory ‧phenomena are always visible on the membrana tympani. One often observes a hyperæsthesia to noises (hyperæsthesia acustica) not proportionate to the disturbance of hearing; this is especially the case in regard to shrill tones, music, and loud speech.

In addition to the subjective noises, the patient often complains of a marked feeling of fulness in the head, a sensation of weight and pressure in the head, stupefaction, and dizziness. The latter symptom, which follows a sudden rise in pressure or congestive hyperæmia in the labyrinth, sometimes occurs with attacks of nausea, vomiting, unsteadiness of gait, marked increase in the tinnitus, and with a sudden, often permanent, diminution in the hearing (Ménière's symptoms); or the attack is less severe, of shorter duration, and disappears without leaving any sequelæ. Psychical depression, inability to think (v. Tröltsch), aprosexia (Guye), and weakness of memory are not infrequent symptoms in this form of middle-ear disease.

Disturbance of Hearing.—The degree of the disturbance of hearing is generally dependent on the extent of the obstruction in the sound-conducting apparatus, and on the simultaneous changes in the labyrinth. Great variations in the hearing distance, especially marked increase, are less often observed here than in the exudative catarrhs. Most patients hear better in the morning than in the evening. Severe deafness of a transient nature is often observed during mastication. Conditions of the weather and marked changes in temperature, in addition to bodily indisposition and general debility, often have a deleterious influence on the function of hearing. According to Urbantschitsch, the function of hearing in one ear decreases for a certain time, while that of the other ear shows a corresponding increase (alternating deafness).

The deafness for speech is most marked. while often very slight noises—as, for example, the fall of a needle—are easily heard. Similarly, persons with a high degree of deafness often hear music and singing rather well when not at too great a distance away. In severe disturbances of hearing, deep tones and pianissimo are no longer heard. The power of hearing better

in noises is not infrequently observed in the adhesive processes, but not as frequent as in otosclerosis.

The perception through the cranial bones for the watch and acoumeter may be normal, but more often, however, it is diminished or entirely absent. This is especially the case in individuals in whom the aural affection dates from childhood; furthermore, in old cases complicated with labyrinthine disease, in emaciated, anæmic, and cachectic individuals, in syphilis and advanced age. The tests with the tuning-fork generally give the results described in middle-ear catarrh (vide Diagnosis).

Concerning the results of auscultation in adhesive processes, the author refers the reader to p. 120.

The decrease in the power of hearing in adhesive processes of the middle ear is seldom uniform. One often observes during the course of the disease intervals in which the deafness either remains stationary or slightly improves. Such intervals may be followed by a gradual or sudden decrease in the hearing, which progresses until the deafness has reached a stage in which it can hardly be benefited, or has become complete. A progressive increase in the deafness develops in these cases just as in the typical forms of otosclerosis. Total deafness is, on the whole, rare. When such is the case, it develops either gradually and without marked symptoms, or suddenly by the intercurrence of a labyrinthine affection, and is then associated with severe tinnitus, dizziness, and fulness of the head. The author regards catching cold, the effect of very loud noises, concussion of the head, mental affections, excesses, brain and spinal cord disease, syphilis and old age, as the most frequent causes of such permanent or transient deafness.

The author would like to lay special stress on the fact that in unilateral deafness of a high degree the tendency of the normal ear to become diseased is considerably increased. Experience shows that when, in unilateral deafness of a high degree the normal ear also becomes diseased, the deafness does not develop gradually, but usually very rapidly, and that not infrequently in a short time the second ear becomes more deaf than the one which had been affected for years.

While, in an overwhelming majority of cases, the affection remains stationary or there is a constant increase in the deafness, patients are, nevertheless, sometimes observed in whom, after a protracted local treatment, a marked temporary or permanent improvement in the hearing suddenly takes place. This is mostly due to an improvement in the permeability of the Eustachian tube, or to the disappearance of an anomaly in tension in the sound-conducting apparatus. Experience has shown that long-standing, chronic middle-ear catarrhs may heal spontaneously with a complete restitution of the hearing—a fact which proves that chronic catarrh of the middle-ear mucous membrane does

not always cause adhesive tissue changes in the tympanic cavity. Finally, it must be mentioned that a serous or mucous exudation in the middle ear may arise in the course of a chronic adhesive process, and that, furthermore, an acute reactive inflammation or an acute perforative suppuration of the middle ear may complicate the process. When this latter complication arises, it goes without saying that a permanent or temporary diminution in the hearing ensues. Only in exceptional cases is a decided improvement in the hearing observed after the reactive inflammation has ceased.

Diagnosis.—The diagnosis of catarrhal adhesive processes in the middle ear is not difficult when the otoscopic examination presents changes in the drum membrane already described. These conditions of the membrana tympani, when taken in conjunction with the course of the disease, the subjective symptoms, the results of the hearing tests, and the auscultation sounds heard during catheterization, will allow us to conclude, in the majority of cases, that the deafness is due to pathological changes in the sound-conducting apparatus.

In addition to these characteristic changes on the membrana tympani, the results of the tuning-fork tests are absolutely necessary for a diagnosis. In unilateral affections, Weber's test is of conclusive value for the diagnosis of an adhesive process in the middle ear only if the perception is lateralized in the diseased ear. In bilateral deafness of a high degree, Weber's test is of less diagnostic value than Rinne's. Marked negative Rinne associated with a failure of perception for the lower tones and lengthened perception for the tone of the tuning-fork through the cranial bones (Schwabach) are the most positive diagnostic signs of an obstruction in the sound-conducting apparatus. If the middle-ear affection is complicated with advanced labyrinthine disease, Rinne's test gives no certain result, inasmuch as the tone of the tuning-fork may not be heard any longer before the ear than on the mastoid process. A marked diminution in the duration of perception for the tone of the tuning-fork through the cranial bones (in persons under sixty years) allows one to assume that the process is complicated with a labyrinthine disease. High tones are heard relatively better than low ones, yet the perception for the highest perceptible tones is often diminished.

Adhesions between the membrana tympani and the inner wall of the tympanic cavity, as well as anomalies of tension in the sound-conducting apparatus, are diagnosed by inspection of the membrane during an inflation, and by the subsequent examination with Siegle's speculum. Thinned parts of the membrane which only lie in contact with the inner wall of the tympanum, or with the incudo-stapedial articulation, bulge forward, like bubbles after an inflation, and show a marked mobility when testing with

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Siegle's speculum. The bulged-out parts either remain in this position for some time or quickly collapse. In like manner one often observes that markedly retracted membranes sink back quickly after an inflation. Where synechiæ exist, however, the sunken adherent places remain unaltered during an air-douche, or when testing with the pneumatic speculum. Bridge-like bands between the membrane and the inner wall of the tympanic cavity cannot be diagnosed by this method, because these striæ often still possess a certain amount of elasticity, and do not retract the membrane.

Anomalies of tension of the membrana tympani cannot be determined by inspection alone. This is explained by the fact that membranes which appear perfectly normal sometimes prove to be abnormally tense or markedly atrophic and very movable when examined with the pneumatic speculum. In like manner one often finds a very cloudy, retracted, apparently thickened membrane highly relaxed when using Siegle's speculum. As the normal membrane presents individual variations of tension, we can conclude that the tension is increased only by a marked diminution in the mobility of the membrane, or its localized parts. On the other hand, a relaxed membrane is determined by its excessive mobility. A marked movement of the handle of the malleus excludes an ankylosis of this ossicle, and also of the incus. In ankylosis of the incus, the mobility of the malleus is also diminished. Limited changes in the tension of the membrana tympani may exist without marked disturbance of hearing.

In a considerable number of cases in which there are pathological changes on the membrana tympani and a slight impermeability of the tube, the progressive course, the subjective symptoms, and the results of the hearing tests are the same as in typical cases of otosclerosis. In many it is exceedingly difficult to make a differential diagnosis. This is based on the fact that, besides adhesive changes in the tympanic cavity, otosclerotic changes are also found in the labyrinthine capsule. Such mixed forms occur rather frequently. It is impossible to make a positive diagnosis, because the catarrhal changes localized in the middle ear often present the same clinical picture. Numerous anatomical and clinical observations are still necessary in order to establish a differential diagnosis between these processes.

Prognosis.—Inasmuch as we have to deal, in catarrhal adhesive processes in the middle ear, with products of disease which have become organized, a complete return to the normal state is out of the question. Our prognosis depends on the course of the disease and on the results of the objective examination—that is, whether in the further course of the disease the disturbance of hearing increases slowly or rapidly.

The prognosis may be said to be relatively more favourable when, in spite of the fact that the disease is of long duration,

the disturbance of hearing is not of a high degree, and the power of perception of the auditory nerve through the cranial bones is not lessened; also, if the affection has run its course without subjective noises, or if they only occur at intervals. The prognosis is furthermore favourable if a marked improvement in the hearing and a lessening of the tinnitus are observed after the inflation of air into the tympanic cavity.

On the other hand, the prognosis is unfavourable where, after a short duration of the disease, a considerable disturbance of hearing has already developed; where the subjective noises continue uninterruptedly; where the perception through the cranial bones is either shortened or entirely absent; and where an increase in the hearing distance after an inflation of air into the middle ear is either imperceptible or very trifling. We may expect a rapid decrease in the hearing in those cases in which the disease has only lasted a short time, and the perception through the cranial bones is already lost. The prognosis is furthermore unfavourable in old and lymphatic individuals, in anæmia, tuberculosis, marasmus, and cachexia, where there is an undoubted hereditary predisposition, and in cases in which harmful influences cannot be removed—in other words, where the external conditions of life, such as calling and occupation, have an unfavourable influence on the course of the disease.

Treatment.—In the treatment of catarrhal adhesive processes our main purpose is not only to improve the power of hearing as much as possible, but also to stay the rapid progress of the disease. Besides this, it should be our endeavour to mitigate the tormenting subjective noises, as well as the troublesome head symptoms which usually accompany this disease.

Inflations of Air into the Middle Ear.—Inflations of air into the middle ear in catarrhal adhesive processes produce much less improvement in the hearing than in the exudative catarrhs; relatively, the best results are obtained by Politzerization, provided that the tube is not strictured to such a degree that air cannot enter with sufficient force into the middle ear. When the tube is permeable, inflations of air through the catheter are less effective than the air-douche according to the author's method. Experience has shown that only in cases of marked stricture of the Eustachian tube, the air-douche by means of the catheter produces not only a more marked improvement in hearing, but also a greater relief of the subjective symptoms. The force of the inflation must be regulated according to the obstruction in the Eustachian tube, and according to the degree of tension of the membrana tympani.

If, immediately after an inflation of air, a considerable improvement in the hearing takes place, a good result may generally be expected from the treatment. It must, however, be mentioned that, in most cases, the improvement in hearing after the

air-douche disappears within twenty-four hours, and a longer continuance of the improvement will be noticed only after its repeated use. It is very important, in the treatment of adhesive processes, that the inflations should not be given daily, but only every second or third day. As a rule, however, we rarely employ the air-douche alone in this form of disease. It is more often used in combination with the introduction of medicated fluids into the tympanic cavity through the tube, and with rarefaction and condensation of the air in the external meatus (pneumo-massage). We have learned from experience that, in the majority of cases, a better result is obtained by the combination of these methods than by the air-douche alone.

The statements of various authors differ greatly as to the results obtained in the treatment of chronic middle-ear catarrh by compressed air in the so-called pneumatic cabinets. V. Tröltsch and Magnus (*A. f. O.*, vol. i.) say that there is absolutely no value in this method of treatment. In the majority of the cases observed by the author, the effect of the pneumatic cabinet in which the air was condensed could not be estimated, because, according to the statement of the patients, Politzerization had been practised simultaneously. In cases in which the patient was exposed only to the effect of the compressed air in the cabinet, the result was less than after the application of the air-douche by the author's method or by catheterization. Only in one case did the author observe a considerable improvement in the hearing after the pneumatic treatment, where formerly local treatment had been without result. Gomperz observed a change for the worse after a pneumatic treatment.

Local Medicinal Treatment.—Medicaments used in the treatment of adhesive processes are introduced into the middle ear either in solution, or in the form of vapours.

The action of drugs may be attributed to the following facts:

1. Since the introduction of vapour, as well as the injection of small quantities of fluid into the middle ear, is always effected by a certain amount of air-pressure, the improvement in hearing must, to a great extent, be attributed to the simultaneous action of the inflations of air.

2. Medicaments introduced into the middle ear cause a more or less marked reactive irritation by which the ligaments of the ossicles, which have become rigid, are loosened, and thereby become more easily stretched after an air-douche.

3. In cases in which there is still swelling of the mucous membrane of the middle ear due to infiltration of round cells, the unorganized, cellular elements may partly degenerate and be absorbed as a result of the irritation set up by the drugs.

Injections.*—In catarrhal adhesive processes, injections of medicated solutions into the middle ear *per tubam* are more often used than vapours. A few remedies which have proved most serviceable are: sodium bicarbonate (℞ natr. bicarb. 0·5, aq. dest. 10·0, glycerin. pur. 2·0, 8–10 drops to be injected lukewarm) causes, after its injection, a slight temporary burning. In adhe-

* Method of injecting fluids into the middle ear, see pp. 122, 123.

sive processes of the middle ear combined with swelling of the tube, it is preferable to employ the muriate of pilocarpine (1–2 per cent. sol.), of which 5–6 drops are injected. This quantity, if injected into the middle ear, produces neither salivation nor sweats. Instead of sterilized, liquid vaselin, which causes no reaction, and which has been recommended by Charles Delstanche, it is better to use, in catarrhs complicated with swelling of the tube, a solution of oleinate of zinc in vaselin (0·3 : 30·0, 15 drops to be injected). In pronounced syphilitic affections of the middle ear, with or without a labyrinthine complication, a solution of potassium iodide (2·0 : 20·0, 10–20 drops) may be used; this must always, however, be combined with a general antisyphilitic treatment. When a coryza or an angina arises from the iodide-injections, they must be stopped.

In cases of marked stricture of the Eustachian tube, the injections must be preceded by dilatation of the tube with suitable bougies (*vide* chapter on Strictures of the Tube).

Of the numerous solutions recommended for injection into the middle ear the following may be mentioned: Caustic potash, in the proportion of 1 : 400 (Pappenheim, Schwartze); lithium carbonate, 0·1 : 30·0 (v. Tröltsch); sal ammoniac, 0·5 : 40·0; chloride of sodium, 0·5 : 15·0; chloral hydrate, for subjective noises, 1·0 : 30·0 (Lucae, Wreden); acetic or lactic acid, 1–5 drops in 40·0 of water; muriatic acid, 1–3 drops in 40·0 of water. The greatest reaction is caused by solutions of potash and soda, acetic acid, nitrate of silver, sal ammoniac, chloride of sodium and copper sulphate (de Rossi).

Injections of irritating drugs which produce a violent reaction must be avoided. Experience shows that sometimes, after the injection of such drugs, a reactive inflammation is brought about, which is followed by a transient improvement in hearing. In the majority of cases, however, this is followed later by a marked change for the worse.

Vapours.—The introduction of medicated vapours into the middle ear for the treatment of chronic middle-ear catarrh is now employed less frequently. They also produce more or less marked irritation to the mucous membrane of the middle ear, whereby the effect of an inflation of air is increased. The question whether injections or vapours afford the best results must be answered by the fact that in some cases the former, in others the latter, prove more beneficial. As a rule, injections are preferable to the introduction of vapours into the middle ear, as they are more convenient, take up less of the patient's time, and are not so annoying. One may try, however, the introduction of vapours when the first few injections prove of no avail, or are even detrimental; in such cases one sometimes obtains better results after the use of vapours.

Sal ammoniac and turpentine vapours (ol. terebinthin. 15·0, mentholi 1·0) were the ones most commonly used, although many other combinations of oils, etc., have lately found their way into

practice. In catarrhs accompanied by continuous subjective noises good results have been obtained from the introduction of vapours of ethyl iodide (Burckhardt-Merian), acetic ether, or a mixture of ethyl chloride, acetic ether, āā 5·0, and tincture of iodine 0·2. The latter may be alternate with injections.

The vapours which were formerly used in the treatment of chronic affections of the middle ear, and which were said to be of special value, are those of steam, sal ammoniac, iodine (Delstanche), acetic acid, acetone, pyroligneous acid, tar (Bonnafont), carbonic acid (Ruete), oxygen (Cozzolino) and hydrogen gas (Löwenberg).

Instead of the irritating drug thiosinamin (15 per cent.), which in the last few years has been recommended by various authors for subcutaneous injection, Merck's sterilized fibrolysin has recently been used. Of a phial containing 1½ c.c. of this solution, at first one-half, and later the entire contents, are injected into the arm, neck, or mastoid process. Siebenmann regards the supposed favourable results as very doubtful, for the reason that, in his clinic, Dr. Mögerle systematically tested a large number of specially selected cases with fibrolysin without the slightest success. One must not place too much importance on the action of fibrolysin, as in some cases of chronic middle-ear catarrh a temporary, marked improvement in the hearing may arise, which may also come on spontaneously from any other form of treatment.

When a catarrhal adhesive process is associated with a retracted membrana tympani, rarefaction of the air in the external auditory canal is a good local therapeutic measure (vide p. 135). It very often brings about not only a striking improvement in the hearing, but also a diminution in the subjective noises and the removal of the troublesome head symptoms (Schwabach, Zeit. für Ohren., vol. xxxix.). Where the membrana tympani is neither retracted nor atrophic, but shows a cloudiness and a diminished mobility, massage with Delstanche's masseur or by means of the electro-motor apparatus is indicated. The strength of the pressure and the duration of pneumo-massage should always be governed by the results in every case. Where, through pneumo-massage, the tinnitus is permanently increased and the power of hearing is diminished—which is not infrequently the case—the use of this procedure must be stopped. Not infrequently massage with Delstanche's hand masseur is more beneficial than that with the electro-motor apparatus. If the pneumo-massage has no effect, we may resort to the 'message-probe' of Lucae. This is hardly ever used, as it is very painful, and usually gives no results.

The result of local treatment depends on the anatomical cause of the disturbance in hearing. As a rule, where the deafness is not great, and where a noticeable increase in the hearing takes place after the first few inflations of air, a better result may be expected than in those cases in which the function of hearing has already considerably deteriorated, and in which no alteration in the power of hearing, or only a slight one, is apparent after the Eustachian tube has been made permeable. One must, however,

be very cautious in the prognosis as regards the results to be obtained from treatment, as one sometimes accomplishes only little in cases which seem apparently favourable, and, reversely, in cases which seem severe, a striking improvement in the hearing sometimes takes place. In like manner, in cases of bilateral catarrh it is often observed (contrary to our expectations) that the power of hearing of the more affected ear is so improved by treatment that it even surpasses the former better-hearing ear. Complete deafness for speech does not exclude the possibility of improving the hearing. For the author has often observed, in cases in which both ears were affected and in which the power of hearing speech in the one ear was quite lost, an improvement in the hearing distance of the deafer ear to the extent of 1 metre during treatment.

The duration of the treatment is of great importance. In most cases a change for the worse takes place after a too protracted treatment. It therefore behoves us to continue the treatment only as long as a steady increase in the hearing distance is observed. If, after treatment for several weeks, no improvement is noticed, the treatment must be stopped, for, if persisted in, the improvement in hearing already attained will quickly disappear again. The length of time it takes to arrive at the best possible result varies greatly; in most cases it ranges between two and six weeks. There are cases in which the greatest improvement in the hearing is observed only after treatment for three or four months and over; such cases, however, are rare.

The increase in the power of hearing is most striking during the first six or eight days of treatment; during the further course the improvement is a gradual one. In some cases an improvement takes place only in the latter stage of the treatment. When the power of hearing is increasing, local treatment often produces a remarkable improvement in the subjective noises and annoying head symptoms. Often, however, the subjective noises remain unaltered, in spite of the fact that an improvement in hearing has been attained. In like manner, one occasionally observes, in cases in which there is no improvement in the hearing, a disappearance of the head symptoms and of the psychical depression.

The author has already mentioned that in unilateral deafness of a high degree the predisposition of the other normal ear to become diseased is very much increased; therefore the occasional treatment of unilateral ear affections is very important. If it is possible to improve the hearing of the affected ear and to prevent it from becoming completely deaf, the normal ear will not be affected as easily as if the process were allowed to pursue its own course until the function of the diseased ear had been completely lost.

The improvement in hearing resulting from the treatment of

catarrhal adhesive processes is rarely a lasting one. In most cases a decrease in the hearing distance is observed a few months after treatment; it is therefore necessary, in most cases, to resort to an occasional after-treatment, in order to counteract the rapid progress of the disease. This consists either in an occasional repetition of the method of treatment previously described, in which case injections and inflations of air are administered alternately, or in the exclusive application of the air-douche at stated intervals. Experience shows that, in many cases in which a steadily progressive decrease in the hearing distance takes place, a repetition of the treatment—once or twice a year for a period of several weeks—causes either a stationary condition of the hearing or retards the progress of the disease.

As an after-treatment the author recommends, in many cases, inflations of air into the middle ear according to his method. Stress, however, must be laid on the fact that repeated daily inflations of air into the middle ear may produce a decided change for the worse in the power of hearing. Therefore, the method should be practised only two to three times a week, and, after its application for three to four weeks, a pause of one, two, or three months must follow. If, at the end of this time, another diminution in the hearing becomes apparent, the inflations should be repeated in the same manner.

Although Valsalva's method is recommended by some aurists, its use should nevertheless be discouraged, for the reason that it may produce a momentary improvement in the hearing, which induces the patient to practise it a great number of times during the day. It has been observed that if the Valsalva method is used too frequently, the hearing distance diminishes, until finally, after its continued misuse, the patient becomes decidedly worse or completely deaf. It is, therefore, the duty of the physician to warn the patients of the evil consequences following the misuse of this method. Similarly, the patient should be cautioned against the abuse of catheterization and Politzerization, as well as the rarefaction of air in the external auditory canal and the pneumatic massage of the membrana tympani.

Strictures of the Eustachian Tube and their Treatment.— Strictures of the tube following middle-ear catarrh are produced either by swelling or tumefaction of the mucous membrane, or by the formation of new connective tissue in the submucous layer; the latter have a tendency to contract, and are known as the true organic strictures of the canal.

Strictures due to swelling are most frequently caused by a catarrh of the middle ear and tube extending from the naso-pharynx; sometimes, however, by primary middle-ear catarrh. The connective-tissue strictures are usually the result of a long-standing, chronic middle-ear catarrh, and are associated with chronic hypertrophic catarrh of the naso-pharynx and ozæna. Besides these, the canal may be narrowed by the pressure of new growths in the naso-pharynx and on the base of the skull; a

relative narrowing, with impermeability, may be produced by inspissated crusts of mucus (Löwenberg).

The seat of the constriction is more often in the cartilaginous than in the osseous portion. The lumen of the osseous portion may be narrowed or obliterated by hyperostoses of its walls, by marked bulging of its anterior inferior wall from the carotid canal, by over-development of the canal for the tensor tympani muscle at the expense of the osseous tube (Zuckerkandl), and by hypertrophy of the mucous membrane, granulations and cicatrices at the pharyngeal orifice of the tube. In the cartilaginous part of the tube strictures are most marked at the isthmus (which is near the place of union of the cartilaginous with the osseous portion); they are not so well developed in the lower part of the tube or at the pharyngeal orifice. Besides intumescence of the mucous membrane, strictures are also caused by a glandular hypertrophy of the mucous membrane, and by the formation of folds and granulations on its surface. The connective-tissue strictures are usually situated in the middle of the cartilaginous portion, in the neighbourhood of the isthmus, often in the isthmus itself, and more rarely in the lower portion of the tube. When the lower portion is narrowed, it may be due to a rhinoscleroma (Gruber, Juffinger, Löwi), or as the result of an ulcerative process extending to the tube from a syphilitic or variolous ulcer of the naso-pharynx. Atresias of the pharyngeal orifice and of the cartilaginous portion (Lindenbaum, Gruber, Hartmann) are rare; they are most frequently found in chronic middle-ear suppuration, at the tympanic orifice of the tube, due to the formation of granulations.

In cases of stricture, examination shows a retracted drum membrane accompanied by changes, which were previously described. It is important, however, to remember that occasionally a marked stricture causes no change in the curvature of the membrana tympani.

When there is a stricture of the tube, an inflation of air into the middle ear meets with great resistance. Valsalva's method and Politzerization are rarely successful. The latter is occasionally successful where air cannot be forced into the middle ear by catheterization.

The nature of the constriction can sometimes be ascertained by auscultation. When the canal is narrowed, due to swelling of the mucous membrane, one hears either an inconstant, sharp and high, or an interrupted, rough, snapping sound which is sometimes combined with a mucous râle. On the other hand, in connective-tissue strictures, the auscultation sound may be entirely absent, or it is indistinct, scarcely audible, and unchanged by the act of swallowing. Occasionally a very high, hissing, whistling and snapping sound is heard during the passage of air through the narrowed portion of the tube.

As a rule, strictures of the tube are accompanied by a high degree of deafness and severe subjective noises. It must, however, be mentioned that there are exceptions to this rule, and that not infrequently the latter may be entirely absent even in cases of marked constriction. A feeling of fulness and pressure in the ear are rarely met with in true strictures; these symptoms are more often apparent when there is a slight swelling at the

pharyngeal orifice of the tube. Annoying head symptoms and occasional attacks of dizziness are often met with in organic strictures.

Diagnosis.—The diagnosis of stricture is made from the marked resistance which is encountered when inflating air into the middle ear by means of the catheter, from the abnormal auscultation sounds, and from the fact that the act of swallowing has no influence upon the auscultation sound. The use of the Eustachian bougie is an important guide in informing us as to the permeability of the tube. One must bear in mind, however, that hindrances to its passage are not sufficient in allowing us to make the diagnosis of stricture, as the point of the bougie, in congenital angular bending of the canal, or through the formation of folds in the tube, may be prevented from proceeding further, in spite of the fact that auscultation shows that air is freely entering the middle ear. In most middle-ear catarrhs unaccompanied by narrowing of the tube, as well as when the Eustachian tube is in a normal state, one observes a freer entrance of air into the middle ear after bougieing. Therefore, auscultation is of diagnostic value only if, after bougieing, a much freer and broader auscultation sound is observed during catheterization—in other words, if a great difference is noticed between the auscultation sound before and after bougieing.

In order to convince one's self that a stricture is due to simple swelling of the mucous membrane, it is recommended to inject 3–4 drops of a 3 or 5 per cent. solution of cocaine and adrenalin into the tube, and in a few minutes to note the results of auscultation; if after such an injection the air enters freely during catheterization, a stricture due to swelling of the mucous membrane may be suspected.

Treatment.—The treatment of strictures of the tube depends on whether we have to deal with a simple swelling of the mucous membrane or with a true organic stricture, and to what extent the lumen of the canal is contracted. Inasmuch as we have already referred to the local treatment of strictures due to swelling on p. 291, the author would like to mention here that, in many cases, a permanent widening is produced by Politzerization alone without any other therapeutic measure; this is proved by the fact that the high-pitched rubbing auscultation sound heard at the first few examinations is changed in the course of treatment to a free, full sound.

By the repeated application of the bougie, followed by the air-douche through the catheter or by the author's method, obstinate strictures produced by swelling are sometimes removed. In other cases, however, an increased swelling and a decided aggravation of the symptoms are immediately brought about by the mechanical irritation of the bougie.

When, in spite of repeated inflations of air into the middle

ear through the catheter, the symptoms of tubal constriction do not disappear, or when at the first examination an organic stricture is diagnosed, it is advisable to introduce a bougie into the Eustachian tube to verify the diagnosis, and at the same time to bring about a mechanical dilatation of the tube.

To dilate the Eustachian tube one may use bougies of silkworm-gut (*Crin de Florence*). These are conical in shape, slightly club-shaped at the point, and covered with a thin layer of lacquer. They possess a certain flexibility, and have sufficient resistance to pass strictures of moderate size. In severe constrictions, however, they seldom suffice, because they lack the necessary rigidity. Therefore, when dealing with such strictures, the author uses the whalebone bougies. They are well polished, and in consequence of their greater rigidity slide more easily through the constricted portion. The point is either conical, olive-shaped, or cylindrical. Each series contains eleven bougies, whose diameter at the point varies from 0·4 mm., 0·5, 0·6, 0·7, etc., to 1·0 mm., so that they can be used for gradual dilatation of the stricture. Celluloid bougies become brittle after using them for a long time. Catgut bougies are particularly suited for the rapid dilatation of strictures, as they possess the property of absorbing moisture. They are also serviceable as medicated bougies, for which purpose the tip should be soaked in a solution of adrenalin (Thost) or nitrate of silver, and carefully dried. Marshall recommends bougies which are smeared with a 3 per cent. mixture of silver nitrate and lanolin. Yankauer also devised a set of bougies, made of silk webbing; they are graduated in size, and are similar to the bougies used for the ureters. Their colour is red with black markings on the outer end, which enables one to tell at a glance how far the end of the bougie has been advanced into the Eustachian tube.

When using the Eustachian bougie, the following points should be observed: In order to cause the patient as little inconvenience or unpleasantness as possible, and to minimize the pain, one should first pencil the nasal passages and posterior nares with a 3 or 5 per cent. solution of cocaine. One should then introduce into the nose a catheter with a rather curved beak, through which a bougie is passed into the orifice of the tube. Having first lubricated the bougie with vaselin, it is pushed forward to the ostium tympanicum tubæ—that is, 1½–2 cm. beyond the mouth of the catheter. Several ink or colour marks at the outer end of the bougie enable the practitioner to control its advance, and to determine the amount of projection beyond the point of the catheter. The catheter is held fast in its place by the bougie.

Pushing the point of the bougie into the tympanic cavity should be avoided, and when using rigid bougies may lead to perforation of the strongly retracted membrana tympani.

The resistance encountered by the bougie in the Eustachian tube is easily overcome in cases of slight stricture. If the constricted portion is short, the bougie will often pass with a sort of jerk. If, however, the stricture involves a greater portion of the tube, there is a considerable resistance. In these cases, the danger of wounding the mucous membrane can be avoided if the bougie is pushed forwards slowly with great caution, and with occasional rotations round its axis. If such cases are treated in this manner,

it is often possible, even after four or five sittings, to pass the narrowest place. When the point of the bougie passes into the Eustachian tube, the patients complain of a stinging sensation in the ear, sometimes in the teeth and in the occiput; in those cases in which, owing to bending, it enters the throat, a stinging sensation is felt in the lateral region of the neck. It should be mentioned that, through forcible bougieing, the mucous membrane of the tube may be injured, and if followed by an inflation of air, a submucous emphysema may be produced (p. 118).

In order to effect a dilatation of the stricture the bougie must remain in position for five, ten or fifteen minutes. If we resort to the auscultation tube while passing the bougie—more often, however, upon removing it—a crackling sound is audible, which may generally be looked upon as a sign of the successful introduction of the bougie.

If catheterization is resorted to immediately after extraction of the bougie, the air is heard to enter the tympanic cavity more freely than before. After the air-douche, there is often a marked subjective relief, as well as a decrease in the tinnitus and a considerable improvement in the hearing. When we meet with such good results after the first trial, it is always advisable to repeat the treatment two or three times a week, to introduce progressively thicker bougies, and to continue the dilatation until the air enters the tympanic cavity during catheterization or Politzerization without resistance.

The treatment of connective-tissue strictures by mechanical dilatation is, as a rule, unsatisfactory. Cases of striking and lasting improvement in the hearing in which, after years, there is no recurrence of the stricture, are very rare. It is probable that many of the cases of cure which have been reported are strictures not due to the formation of connective tissue, but to simple swelling of the mucous membrane lining of the Eustachian tube capable of resolution. In the majority of cases, the stricture returns after a few months with a corresponding decrease in the hearing distance previously gained, and an increase in the subjective noises. If the treatment by dilatation is again renewed, the result will not be as good as that obtained at the first treatment on account of the progressive tissue changes which have been going on continuously in the tympanic cavity. Nevertheless, in cases of true stricture of the tube, the author looks upon the introduction of bougies as a valuable procedure, because at least a temporary improvement in the hearing takes place, the often unbearable subjective noises are toned down, and the rapid progress of the disease is also checked. We must not forget to mention that in many cases no dilatation is effected in spite of long-continued treatment, and that sometimes, on the other hand, there is neither an increase in the hearing nor a decrease in the tinnitus, in spite of a successful dilatation. In a similar manner one also

observes that, in quite a number of cases, an aggravation of the local symptoms, such as an increase in the impermeability of the tube, a decrease in the hearing and an increase of the subjective noises, are produced by the introduction of the bougie; at times even a middle-ear inflammation is brought about. Therefore the author limits the use of the bougie only to such cases in which the stricture of the tube cannot be treated by any other measure.

From observations made by Weber-Liel, that the simple introduction of a bougie into the Eustachian tube suffices to effect a temporary improvement in the hearing, Urbantschitsch proposed using the bougie in those cases in which there is no stricture of the tube. In cases of catarrhal swellings, as well as in cases with a normal pervious tube, an improvement in hearing and a decrease in the tinnitus is often produced by pushing to and fro a bougie provided with a bulbous point (massage of the Eustachian tube, 1–5 minutes). According to Urbantschitsch, this improvement depends on a reflex in the auditory centre produced by irritation of the sensory branches in the tube; this effect is very transient, as all such reflexes are. The same is true of bougieing the Eustachian tube combined with vibratory massage of the parts between the inferior maxilla and the mastoid process.

The patient's surroundings and the condition of his general health must be taken into consideration in the treatment of middle-ear catarrh. This applies to the chronic non-suppurative, as well as to the suppurative middle-ear processes. It is important that the patient should avoid, as much as possible, all detrimental influences caused by calling and occupation, as well as living in unfavourable localities. The diet should be regulated in each individual case; alcoholic beverages should be limited to a moderate quantity, and only a moderate amount of smoking allowed, especially when the indulgence in these luxuries has a detrimental influence on the deafness and tinnitus. Cold baths and sea-baths often produce an aggravation of these conditions, and therefore patients should be warned against the evil effects of cold head-douches. In catarrhal adhesive processes, hydropathic treatment is sometimes followed by good results, for in many cases sea-baths and cold-water cures have a beneficial effect on the hearing and subjective noises (Winternitz). Cold-water cures have absolutely a bad effect upon the hearing in anæmic, decrepit individuals, and in otosclerosis.

Change of air and residence in a mountainous region often have a good effect upon the course of exudative catarrhs. The author has not infrequently seen complete recovery take place, in cases in which treatment was given for months without effect, after the patient had remained in a high altitude for several weeks. It is therefore recommended in obstinate cases to send the patient to a woody or mountainous region; this applies especially to weak, anæmic, and scrofulous individuals. Changes of air and climate have not a very marked effect upon the course of advanced adhesive processes in the middle ear; it is nevertheless always advisable, even in these cases, to send the patients to a mild

southern climate, especially, if in a northern locality, they are often subject to naso-pharyngeal catarrh.

Internal and External Medication.—The internal treatment of the adhesive processes, to which some aural surgeons attach much importance, is of little value, with the exception of those cases in which a constitutional disease is present. If the latter is the case, the good effect of internal treatment on the course of the aural affection cannot be denied. In general syphilis the local treatment of the aural affection must be combined with a general antisyphilitic treatment. Salvarsan must be given in these cases, and may be combined with the internal administration of mercury or the iodides. In lymphatic individuals, the internal use of the iodide of potassium or iron is very effectual; and in anæmic, debilitated patients the easily-soluble preparations of iron must be prescribed. The internal treatment of catarrhal adhesive processes, accompanied by symptoms of a labyrinthine affection, as well as the treatment of subjective noises associated with these processes, will be described with diseases of the internal ear.

Medications applied externally in the vicinity of the ear or in the external auditory canal are useless. The application of counter-irritants to the mastoid process, as well as painting it with tincture of iodine and rubbing it with ointments, are also of little value.

The Operative Treatment of the Catarrhal Adhesive Processes in the Middle Ear.

1. Artificial Perforation of the Membrana Tympani.

Historical.—Attempts to restore the power of hearing by excision of a part of the membrana tympani date back to the seventeenth century.* The first scientific information in reference to artificial perforation of the membrana tympani dates from the beginning of the nineteenth century. Himly and Astley Cooper performed this operation independently of each other, and, encouraged by the favourable results obtained in the beginning, highly recommended its introduction into practice. It was not long, however, before these two operators became convinced that these startling results were only temporary, inasmuch as the artificial opening invariably closed by the new formation of cicatricial tissue.

Himly deserves the credit of having put a stop to this destructive procedure, which was still practised for a long time in Germany and France to the detriment of many patients. He demonstrated that a slight improvement in the hearing was obtained only in very rare cases, while in the majority of patients

* Compare Politzer, *Geschichte der Ohrenheilkunde*, vol. i., p. 336.

the former degree of deafness returned after closure of the perforation, and frequently even a striking diminution in the hearing power was observed.

The unfavourable results obtained by this operation and the impossibility of keeping the aperture in the membrana tympani open were the reasons why this procedure became obsolete. It was not until the beginning of the ' sixties ' of the nineteenth century that this operation was again put into practice. No new attempts were made, however, to keep the aperture in the membrane open, and after unsuccessful trials the same negative results were attained as those of Cooper and Himly. At the present time this procedure is rarely undertaken, as the results are very uncertain and unsatisfactory, and the danger of infection to the middle ear cannot always be avoided. The chances of improving the hearing are so remote, and so little is gained, that it has been justly discarded.

Indications.—In making an opening in the membrana tympani we equalize the difference in the air pressure between the tympanic cavity and the external atmosphere, and create a direct passage for the waves of sound to the labyrinth. This applies to all cases in which the propagation of sound from the membrana tympani to the stapes is interfered with.

The pathological changes which indicate artificial perforation of the membrane are: (1) abnormal thickening and extensive, firm calcification of the membrane; (2) ankylosis of the malleus and incus owing to immediate or ligamentous union with the tympanic walls; (3) firm, irremovable strictures and adhesions of the Eustachian tube (Cooper); (4) intense and troublesome subjective noises, if they are due to stricture of the tube and cannot be alleviated by bougieing; (5) marked impairment in the sound-conducting apparatus due to firm ankylosis of the ossicular chain.

When we have made an artificial opening in the membrana tympani, the waves of sound reach the foot-plate of the stapes directly, and are thus communicated to the labyrinth without the aid of the membrana tympani, malleus, and incus. The operation can be successful, therefore, only if the stapes is still movable, if the membrane of the round window is not thickened or calcified, and if there is no labyrinthine complication. Before undertaking this operation, a thorough functional test must be made as to the normal perception for the watch through the cranial bones (Astley Cooper) and the lengthened perception for the tone of the C tuning-fork on the mastoid process (Schwabach). In other words, we must be convinced that the labyrinth is in a normal state and that bone conduction is fully preserved. In cases in which the perception through the cranial bones is diminished or entirely absent, no improvement can be expected from this operation.

Methods of Operation.—In order to make an artificial perforation of the drum, we resort (1) to excision of a portion of the drum with a small delicate knife; (2) destruction of the layers of the drum with various caustics; and (3) burning a small hole in the membrane by means of the galvano-cautery. For this purpose we use a simple pointed cautery point, which is heated to a red glow and gently applied to the drum, destroying as much of the tissue as desired. Inasmuch as these procedures are associated with a great deal of pain, it is necessary first to thoroughly anæsthetize the drum and surrounding area with some local anæsthetic, or, better still, to give a mild general anæsthesia. In using the cautery point we must avoid all pressure, as the point of the cautery might easily be pushed as far as the inner tympanic wall, and, by injuring the mucous membrane, give rise to a marked inflammatory reaction. In order to avoid this, it is advisable to select the anterior inferior or the posterior inferior quadrant of the membrane as the seat of operation, as these parts are farthest from the inner tympanic wall.

After an artificial perforation has been produced, it is not infrequently found that there is a striking improvement in the hearing and a diminution in the subjective noises. From this fact it may be assumed with probability that there are no marked changes in the windows of the labyrinth.

In cases in which there are pathological changes in both fenestræ or in the labyrinth, no improvement in the hearing will be noticed after the operation, or, if so, only one of a very moderate degree.

A favourable result following an artificial perforation is of short duration, and may be explained by the fact that it is only in exceptional cases that the opening does not close within a short time by the formation of cicatricial tissue. The disturbance of hearing and the subjective noises return to their former state, or become more aggravated than before the operation. Only a few cases have been observed, however, in which a decided improvement in the hearing remained after closure of the aperture in the membrane. The author has repeatedly seen the aperture remain persistent after a middle-ear suppuration of long duration which had been caused by artificial perforation of the membrane. It is also impossible to keep the perforation open and to prevent a regeneration of the membrana tympani by detaching the annulus tendinosus (Kessel)[*] at the posterior circumference of the membrane, and by excision of the entire drum-head with the hammer (Miot).[†]

Attempts to keep the perforation open by inserting catgut strings, small fish-bone plugs, lead wires, silver cannulas

* *Oesterr. ärztl. Vereinszeitg.*, 1879.
† *Revue de laryngologie*, vol. xvii., 1896.

(Bonnafont), small hard rubber pegs (Politzer), and small gold tubes (Voltolini), have proved unsuccessful. All these contrivances are sooner or later expelled, with or without a suppurative inflammation, whereupon the defect in the membrane becomes cicatrized.

Although the numerous trials have proved unsuccessful, it may, however, be possible, through continued endeavours in this direction, to discover a method by which we shall be able to keep an artificial perforation of the membrana tympani from closing. It is a fact that perforations of the membrane, which are produced by a suppuration of the middle ear, remain persistent during the life of the patient owing to epidermization of their borders. We even find that when the margins of such a perforation are again deprived of their epidermis the aperture cannot be made to close. The desired object of keeping the artificial perforation persistent may be attained if it is possible to create the same conditions which tend to keep the aperture from closing in pathological cases. There is no doubt, according to the author's investigations, that this is occasioned by the growth of the epidermis of the external surface of the membrana tympani over the edges of the perforation into the tympanic cavity.

2. Division of the Posterior Fold of the Membrana Tympani.

Division of the posterior fold of the membrana tympani was recommended by the author in the year 1871,* and by Lucae.†
This procedure is indicated in those forms of catarrhal adhesive processes of the middle ear in which the objective parts of the membrane are very prominent owing to abnormal retraction (*vide* p. 277), and in which, after an air-douche, there is an improvement in hearing of short duration. If this condition of the membrane is associated with a high degree of deafness and severe subjective noises, which cannot be improved by the methods of treatment already described, it is advisable to divide its posterior fold. The increased tension of the posterior superior quadrant of the membrana tympani, which is especially important for the conduction of the waves of sound, is thus overcome, and the handle of the malleus acquires a greater mobility.

Fig. 146.

Operation.—To divide the posterior fold of the membrane the author employs a small, sharp knife, rounded at the end, and bent at an angle to its handle (Fig. 147). Having first

* *Ueber Trommelfellnarben, Wiener med. Wochenschrift*, 1871.
† Langenbeck's *Arch. f. Chirurgie*, vol. xiii.

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anæsthetized the drum, the incision is made perpendicularly to the long axis of the fold from above downwards, at a point directly behind the short process of the malleus, or midway between it and the peripheral extremity of the fold (Fig. 146). Division of this part of the membrane is, as a rule, accompanied by a grating noise; the edges of the wound recede from each other and the handle of the malleus, which was drawn inwards, assumes a more vertical position. The slight hæmorrhage which arises after this operation can be arrested by the introduction of small cotton tampons. It very rarely happens that the chorda tympani is cut; when this is the case, however, the patient experiences a temporary loss of taste on that side of the tongue corresponding to the injured nerve.

Results of the Operation.—The most striking effect of this operation is its power of diminishing the intensity of the subjective noises. The improvement in hearing for speech sometimes increases to 4 or 5 metres. Where, after the operation, no improvement in the hearing takes place, it must be concluded that there is a marked obstruction to the conduction of sound in the ossicular chain or in the windows of the labyrinth.

In reference to the result of this operation, the author found that not infrequently, after several months, the hearing distance gradually returned to its former limit, and that the subjective noises became more intense; this applied even to those cases in which a striking increase in the hearing and a diminution in the subjective noises were noticed immediately after the operation. The author was able only in a very limited number of cases to note an improvement in hearing which lasted for several years.

Fig. 147.   Division of the anterior ligament of the malleus is another operative procedure which must be mentioned, and which the author has repeatedly performed with success. In experiments in which he endeavoured to ascertain the relative tension of the sound-conducting apparatus, he found that the handle of the malleus, which protruded outwards, always had a tendency to spring markedly inwards after the tendon of the tensor had been severed, and after the incudo-stapedial joint and the check ligaments of the hammer had been divided. When, however, the anterior ligament of the malleus (anterior part of the axis ligament) was cut through, the handle of the malleus no longer recoiled inwards. From this fact it may be inferred that this ligament has an important bearing on the position of the manubrium and on the tension of the membrana tympani. It is therefore indicated to sever the above-mentioned ligament in those cases in which there is a marked retraction of the mem-

brane, and in which a striking improvement in the hearing lasts only a short time after the repeated application of the air-douche. The operation, which is easily carried out and free from danger, is performed with a small, narrow, slightly curved knife, sharp at its point and on its concave side (Fig. 147). The operation is performed as follows: Having anæsthetized the drum, the anterior fold of the membrana tympani is first divided; the knife is then inserted directly in front of the short process of the malleus and advanced 2 mm. towards the tympanic cavity. When in this position, an incision from below upwards as far as the Rivinian segment is made, whereupon the anterior ligament of the malleus is divided. In several cases, the effect of the operation was noticed in an immediate diminution in the subjective noises, and a marked, permanent improvement in hearing for the acoumeter and speech. There were some cases, however, in which the success was only temporary.

Multiple incision, which has been recommended in cases in which the membrana tympani is abnormally tense and thick, has almost always a temporary effect; a slight improvement seldom remains for any length of time after the operation (Stelter, *A. f. O.*, 1892). On the other hand, the author has observed in atrophic retracted membranes a lasting improvement in the hearing follow repeated incisions of the flaccid portions. Often, however, the favourable result obtained by this operative measure, as first proposed by the author, is also of a transitory nature.

3. Tenotomy of the Tensor Tympani and Stapedius Muscle.

Division of the tendon of the tensor tympani, as recommended by Hyrtl in his *Topographischer Anatomie*, 1847, was first performed on the living by Weber-Liel in the year 1868. By this operation we are able to overcome the abnormal tension of the membrana tympani and joints of the ossicles, which has been caused by the contraction of the tendon of the tensor tympani muscle (Walb, Schwartze's *Handbuch d. Ohrenheilk.*, 1893).

Up to the present, we possess no objective symptoms which allow us to conclude with certainty that we are dealing with a contraction of the tensor tendon. The familiar characteristic appearance of the markedly retracted membrana tympani (Figs. 125 and 126) may be regarded as the most important objective symptom of a contraction of the tensor tendon. This condition is also brought about by impermeability of the Eustachian tube, by adhesion of the drum-head with the inner wall of the tympanic cavity, and by a ligamentous growth of the malleo-incudal articulation with the external wall of the tympanum. From the foregoing it will be seen, therefore, that it is impossible to conclude with certainty that there is a

simultaneous, secondary retraction of the tendon of the tensor tympani.

The striking improvement in hearing which is sometimes obtained after an inflation of air in cases of marked deafness, and which disappears again after a few minutes, or even a few seconds, is also of little value in establishing the diagnosis of shortening of the tensor tendon. This is explained by the fact that a rapid diminution in the hearing after an inflation of air can also be produced by the stretching and rapid recoil of the above-mentioned adhesive bands. For the same reason, when we find the membrana tympani retracted, we must not consider an abatement in the subjective noises or the relief of dizziness, through rarefaction of the air in the external auditory canal, as a diagnostic symptom of shortening of the tensor tendon, inasmuch as the same effect is observed when the membrana tympani is retracted owing to adhesive bands.

From the foregoing, the indications for cutting through the tensor tendon are still very ill-defined, as often, besides such a shortening of the tendon, there are obstructions to the conduction of sound in the ossicles and in the labyrinthine windows, which are in no way affected by this operative measure. Tenotomy of the tensor tympani may therefore be used only as an experimental procedure, the result of which can never be foretold.

Operation.—The division of the tensor tendon is performed by some specialists by introducing the knife in front of the handle of the malleus, by others behind it. By selecting the latter situation the operation may be carried out far more safely and with greater certainty.

The operation is performed as follows: Having anæsthetized the drum, a small knife, curved on the flat and rounded at the end, is introduced behind the handle of the malleus into the tympanic cavity, and the tendon cut from above downwards. This mode of procedure is more difficult than dividing the tendon by a cut from below upwards. The tenotome of Hartmann (Fig. 148) is the most practical instrument for this purpose; it consists of a small knife curved on the flat and on the edge, the point of which extends 1 mm. beyond its upper edge.

In order to judge the beneficial results obtained by this operation, it is recommended to incise first the posterior segment of the membrane about 1 mm. behind the upper part of the handle of the malleus, and then to test whether any changes have

Fig. 148.—Hartmann's Tenotome for the Right and the Left Ears. (Handle for it, v. p. 287.)

taken place in the hearing distance and in the subjective noises. The tenotome is then advanced 3 mm. into the tympanic cavity through the incision previously made, and is thus brought between the handle of the malleus and long process of the incus, below the tendon of the tensor. The handle of the instrument is now gently depressed, whereby the sharp point of the tenotome is forced towards the upper tympanic space; if the instrument is now withdrawn it severs the tendon; this is accompanied by a distinct cracking noise. The operation is occasionally followed by a rather intense.effusion of blood into the tympanic cavity, which is absorbed within a few weeks. Division of the chorda tympani with a transient alteration in the sense of taste cannot always be avoided.

Results of the Operation.—The handle of the malleus assumes a more vertical position immediately after this operation. In those cases, however, in which its position remains unaltered it must be concluded that the head of the malleus has become fixed through connective-tissue adhesions.

According to the unanimous opinion of Pomeroy, Bertolet, Orne Green, Kessel and Cholewa, we may regard a diminution in the subjective noises as an immediate effect of tenotomy. The majority of the cases reported, however, cannot be used as examples in judging the effect produced by tenotomy, owing to the failure to observe what effect the incision in the membrane and the plicotomy alone had upon the subjective noises before the tendon of the tensor had been severed.

The influence of tenotomy on the power of hearing is considerably less; a striking beneficial effect has only seldom been observed. In the majority of cases, the hearing distance remains unaltered, or the increase is only a slight one; there are even instances in which a decided change for the worse has been noticed after the operation.

This operation, which was introduced in the eighties of the last century, and of which a great deal was expected, was almost entirely given up owing to the poor results. That there are a few cases in which tenotomy may be of value is beyond doubt. As such, the author would like to mention the middle-ear catarrhs which run their course with symptoms of labyrinthine irritation, and are associated with a marked retraction of the membrane; in these cases, after an unsuccessful local treatment, tenotomy of the tensor tendon may be tried. The author had occasion to observe two cases which were accompanied by severe Ménière's symptoms and a marked retraction of the membrana tympani; tenotomy of the tensor tympani was performed in both instances, and was followed by an alleviation of the dizziness and a decided improvement in the hearing function. Lacourret* describes a

* *Vertige auriculaire et spasme du muscle tenseur. Revue hebdom. de laryng.*, etc., 1896.

case of spasm of the tensor tympani which was accompanied by frequent attacks of dizziness, and which was preceded by a cracking sound. The affection is supposed to have been cured by tenotomy of the tensor tendon.

According to our present knowledge, no indications for teno-tomy of the stapedius in non-perforative processes of the middle ear can be established; all that has been previously discussed in reference to this subject has been based upon hypothetical grounds. On the other hand, however, we find that this opera-tion is occasionally of value after a middle-ear suppuration has run its course—in other words, where the tendon of the stapedius has become imbedded in the cicatricial thickening of the mucous membrane of the tympanic cavity.

The operative procedures which, in former years, were fre-quently practised in the non-suppurative middle-ear processes, such as mobilization of the stapes, synechotomy of the crura of the stapes, and excision of the entire membrane with the hammer and incus, have not fulfilled the expectations which were attributed to them; the successes which have been reported have been reduced to a minimum. As these procedures have been recognized to be practically worthless, the author thinks that it is useless to go into a full description of their technic; the more so because the intratympanic operations in adhesive processes after a chronic middle-ear suppuration has run its course, in which certain surgical procedures (in reference to an improve-ment in hearing) give a favourable result, will be spoken of more fully later.

Otosclerosis.*

Long before the anatomical conditions of this special form of disease were known, various authorities raised the question whether the so-called dry middle-ear catarrhs running their

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* This aural affection has erroneously been called ' dry middle-ear catarrh ' (*otitis media catarrhalis sicca*). In its typical form it must be separated from the group of middle-ear catarrhs on account of its important anatomical characteristics. Roosa terms it ' proliferous inflammation of the middle ear '; De Rossi, ' otite media iperplastica.' . Siebenmann, who likewise thinks that the affection is a primary disease of the labyrinthine capsule, and whose thorough histological examinations deserve full credit, has proposed the name ' spongoid transformation of the labyrinthine capsule ' for this form of disease. It would not be consistent to accept this anatomical name for typical cases of otosclerosis, as analogous changes also occur in adhesive middle-ear processes. Besides, the anatomical conditions in otosclerosis are not exactly the same as in normal spongy tissue. The symptomatic classification, ' progressive deaf-ness,' selected by Weber-Liel and Lucae, is just as little applicable, inasmuch as this form of disease is also observed in the nervous progressive deafness described by Manasse.

As the name otosclerosis has already found its way into otology, the author would therefore like to limit this term only to the clinical, sharply-defined, typical form of this disease about to be described.

course with progressive deafness should be classed among the true catarrhal processes of the midlde ear. V. Tröltsch was the first to express the opinion that this form of disease could, through a broadening of our anatomical knowledge, be given a separate place in the category of diseases of the ear. In previous publications,* the author has called attention to the fact that when we meet with that form of progressive deafness which runs its course from the very beginning without any catarrhal symptoms, we must regard it as a special disease of the organ of hearing; such an affection presents an entirely different character from the adhesive processes secondary to catarrhs. The pathological investigations, which have only been carried on extensively within the last few years, have, to a certain degree, given us a clearer idea of the nature of this disease. While investigating this subject, the author had the opportunity of clinically observing, for a great many years, a vast number of cases at the Vienna General Alms House, and also had occasion to examine their organs of hearing at the *post-mortem*. His examinations demonstrated beyond doubt that cases which, on account of their clinical course, we had very often been accustomed to place among the chronic, dry, middle-ear catarrhs, did not present a diseased condition of the mucous membrane of the tympanic cavity, but a primary affection of the labyrinthine capsule.

In reviewing the older literature, various conditions are described which, without doubt, should be placed in the group of primary affections of the labyrinthine capsule, but which were classified under a different anatomical division. In Toynbee's catalogue of 1837, he describes a thickening of the ankylosed foot-plate of the stapes, and an overgrowth of its anterior two-thirds by a bony mass resembling ivory, which had originated from the vestibular surface of the labyrinth. Moos describes a case which he observed during the life of the patient, and which he examined at the *post-mortem ;* he found that the stapes was ankylosed by the development of bony tissue from the wall of the promontory, and that the internal auditory canal was narrowed to a slit, without any change in the mucous membrane of the middle ear.

In the year 1889 † the author described a case in which an accumulation of new-formed bony tissue was found upon the inner surface of the foot-plate of the stapes, and in the region of the fenestra ovalis; in 1893 ‡ he published three cases of deafness in which the stapes was fixed in the pelvis ovalis, through a hyperostosis on the promontory; these conditions clearly showed that these cases belonged to the group of primary affections of the labyrinthine capsule.

Katz§ records a case of ankylosis of the stapes which he regards as the sequel of an independent inflammation of the ligamentum orbiculare stapedis, from which the disease extended to the cartilage and bone. Habermann,‖ who described a case belonging to this group, considers the changes found in the labyrinthine capsule as the result of an inflammation of the mucous membrane and periosteum of the tympanic cavity.

The author was in a position, in the spring of 1893, to demonstrate to Professor Weichselbaum the microscopic specimens of eight cases which he

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* *Lehrbuch*, 3. Aufl., p. 235.　　　† *Ibid.*, 2. Aufl., p. 233.
‡ *Ibid.*, 3. Aufl., p. 239.　　　§ *Deutsch. med. Wochenschr.*, 1890.
‖ Schwartze's *Handbuch*, p. 249.

had observed during the lives of the patients; in these sections, a circumscribed osseous growth and tissue changes in the labyrinthine capsule were clearly demonstrable. In the summer of the same year the author read a paper before the Pan-American Congress at Washington in which he openly expressed his views, based upon the observation of ten cases, as to the nature of this form of disease, and expressed the opinion that this affection was a distinct entity. Since that time his findings have been substantiated by many pathological investigations.

We must finally mention the case of Bezold-Scheibe published in the autumn of 1893 (*Z. f. O.*, vol. xxiv.). The patient was a woman, sixty-five years of age, who had been deaf for thirty-eight years, and whose loss of
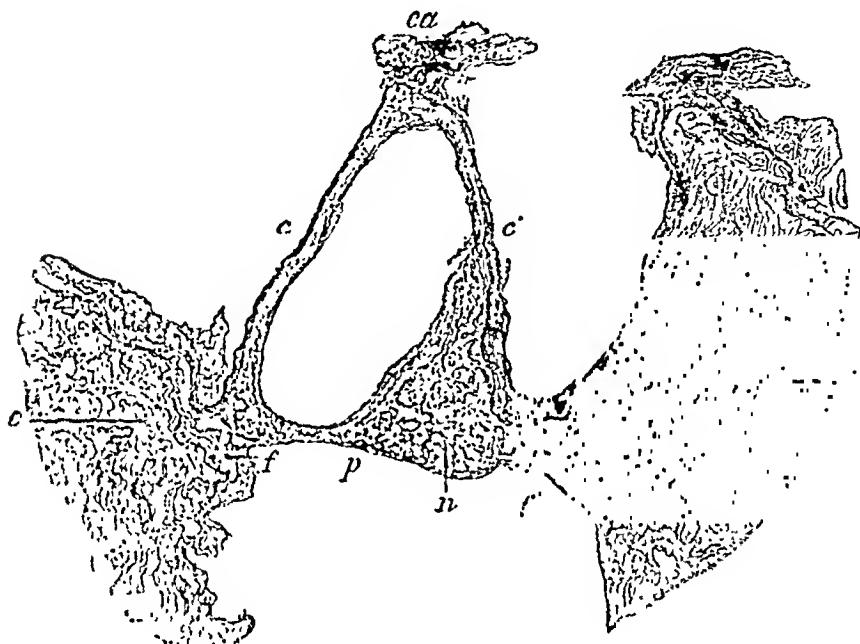
Fig. 149.

hearing followed an attack of typhoid fever; in this case, a bony ankylosis of the stapes was discovered, which had been produced by an inflammatory condition of the bone in the neighbourhood of the foot-plate, and which, according to Bezold-Scheibe, probably originated from the periosteum of the recess of the oval window, if not from the bone itself.

Other very instructive publications, which contain anatomical and histological conditions regarding otosclerosis, have been contributed by Siebenmann, Manasse, E. Hartmann, Jörgen Möller, G. Brühl, Stilling, Lindt, and others.

The Pathological Changes.*

The macroscopic condition of those cases examined by the author, of which only a few of the most typical will be given here, was varied. In a great number of specimens, bony protuberances were found which were more or less sharply defined and were about the size of a small lentil; these were situated on the promontory in the neighbourhood of the recess of the fenestra

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* Cp. A. Politzer, *Ueber primäre Erkrankung der knöchernen Labyrinthkapsel. Zeitschr. f. Ohrenheilk.*, vol. xxv.

vestibuli, and stood out prominently from the surrounding area owing to their pale yellow or reddish colour. In other cases the entire recess of the fenestra vestibuli was narrowed through bony growth, the stapes tightly immured in the narrowed recess, the promontory thickened, and the recess of the round
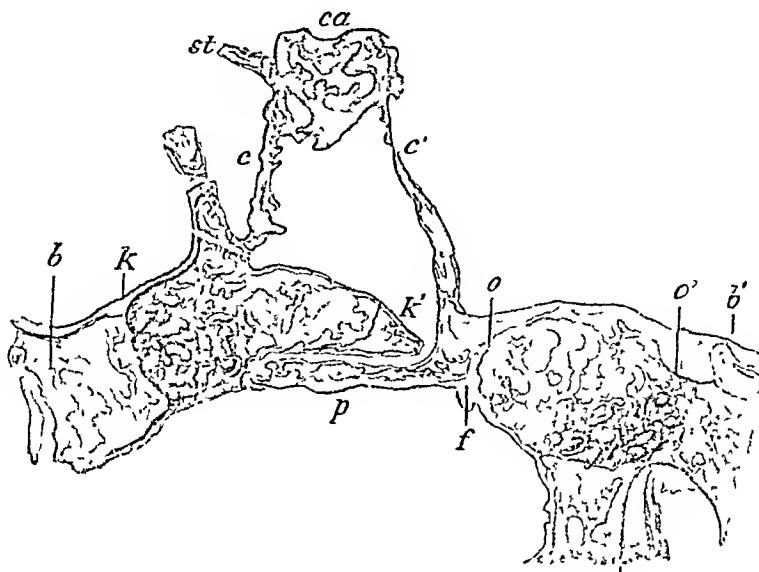
Fig. 150.

window reduced to a cleft. In the majority of the specimens, the mucous membrane of the tympanic cavity did not present the least change from the normal. In two cases the mucous membrane of the cavum tympani was thickened and gray, similar to that met with in the catarrhal adhesive pro-
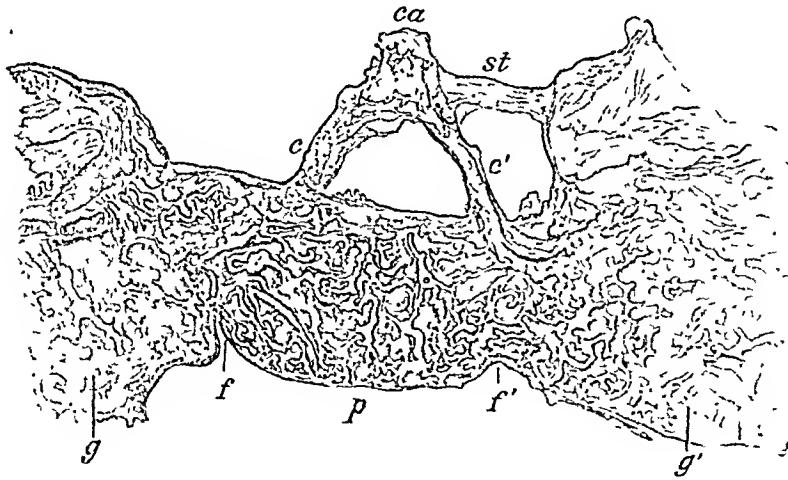
Fig. 151.

cesses, and the depressions and recesses in the lateral walls of the cavity, especially the attic and the recesses of the windows, were traversed by thickened bands of connective tissue.

In sections of decalcified bones, the conditions found in the different stages of the process showed great variations. In a number of the speci-

mens, a sharply-defined, bony new formation in the labyrinthine capsule was observed in the neighbourhood of the fenestra vestibuli; this bony mass could be differentiated from the normal osseous tissue by its deep carmine stain, and by the marked enlargement of the bone-spaces and Haversian canals. A portion of the ligamentum orbicularis stapedis was displaced by this new osseous growth, and a part of the rim of the foot-plate of the stapes was firmly united with it. In another specimen (Fig. 149), the growth of the bone had already advanced to such an extent towards the fenestra vestibuli that it nearly filled the angle (n) formed by the foot-plate and anterior crus of the stapes. In another case (Fig. 150), in which the process was further advanced, a sharply-defined plate of bone (o, o') was seen at the anterior part of the fenestra vestibuli; this growth involved the entire labyrinthine wall and displaced the annular ligament of the stapes; at the posterior part of the

FIG. 152.

fenestra vestibuli, a bony new formation of a similar structure was discernible (k, k'); this had grown into the fossula fenestræ vestibuli, and enveloped the external surface of the foot-plate of the stapes (p) without reaching the opposite border of the fenestra vestibuli.

The author must finally record those cases in which the anatomical changes were further advanced; in these specimens, the entire fossula fenestræ vestibuli was filled with a bony mass displacing the stapes, or (Fig. 151, f, f') was closed by a dense new bony formation, which, without any line of demarcation, extended into the pathologically altered labyrinthine capsule (g, g'). The boundaries of the former plate of the stapes were indicated by two well-marked depressions (f, f') on the vestibular side. The foot-plate itself and the inner part of the crura were imbedded in this bony tissue, which completely filled the fenestra vestibuli and the inner part of the recess. The external portion of the crura (c, c') was not involved, and passed over into the newly-developed osseous mass. It was evident that the diseased condition of the bone had

extended over a large part of the labyrinthine capsule. In the left ear of the same individual, the fenestra vestibuli was similarly occluded by the new formation of bony tissue. In this ear the growth, however, advanced to the cochlea (Fig. 152), the scala tympani of which was completely filled by a dense bony mass (*st*), which united it with the labyrinthine capsule; it was also observed that this new formation extended to the inferior surface of the lamina spiralis. The pathological changes in the labyrinth which have thus far been found in otosclerosis are: osseous new formations, atrophy of Corti's organ (Politzer), atrophy of the acoustic nerve in the cochlea and of the ganglionic layer in the spiral ganglion (Bezold, Scheibe, Habermann), and atrophy of the origin of the acoustic nerve (Brühl).

  The cases examined histologically by the author showed a new bony formation which had developed in the capsule of the labyrinth. The specimens under the microscope showed the characters of vascular, young bone, which was produced from a chronic ostitis and which pushed aside the normal osseous tissue of the labyrinthine capsule.

The newly-formed bone is characterized by the immense size of its spaces and Haversian canals. The osseous spaces are filled with connective tissue, rich in cells, which surrounds large and small bloodvessels. In addition to these pathological conditions, the author has frequently found osteoblasts and osteoclasts scattered along the course of the bloodvessels. The bone corpuscles in the pathologically altered tissue appeared more numerous and more compact than under normal conditions.

The author's view, that in typical cases of otosclerosis the osseous disease is a primary affection of the labyrinthine capsule, is substantiated by the clinical and anatomical investigations of Siebenmann, E. Hartmann, Jörgen Möller, and others. On the other hand, Habermann, Katz, Schilling, and Lucae believe that the disease arises from the mucous membrane; in other words, from the periosteum of the middle ear. For typical cases of otosclerosis, this theory cannot be accepted because, first, in no case in which the seat of the affection was in the promontory wall was the extension of the process towards the deeper layers seen to come from those parts of the bone near the periosteal layer; the osseous disease was seen to be more in that part where it did not appear as a circumscribed island in the labyrinthine capsule, but took in the entire thickness of the promontory wall. Secondly, Jörgen Möller, Lint, and the author found circumscribed, sharply-defined nodules of new bone in the labyrinthine capsule, between which and the periosteum there was a normal layer of bone. In one case, Manasse found in both ears an isolated, newly-formed osseous mass in the internal auditory canal. Thirdly, the author did not find in his histological examinations of typical forms of otosclerosis the slightest change in the middle-ear mucous membrane and in its periosteal layer.*

The investigations of the author, Manasse, and Habermann have shown that, in non-suppurative adhesive processes of the middle ear, analogous changes in the labyrinthine capsule may also develop. Numerous anatomical and clinical investigations must prove whether they are the consequence of a middle-ear disease. In a few cases of chronic middle-ear suppuration Manasse and Habermann have seen analogous osseous changes in the labyrinthine capsule. That, in such cases, we are not dealing with a sequela of the middle-ear suppuration, but with a combination in which each disease develops independently—the appearance of a middle-ear suppuration in an individual suffering from otosclerosis—is proven by the fact that the author, in the many cases of chronic middle-ear suppuration examined histologically by him, never saw otosclerotic changes in the labyrinthine capsule.

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* The view that a disease of the middle-ear mucous membrane which causes such severe and deep-seated changes in the osseous tissue of the labyrinthine capsule may heal so completely as not to leave a trace of any pathological change in its layers cannot be accepted by any pathologist.

Etiology and Occurrence.—Clinical observations have demonstrated that heredity plays a very important part in the etiology of otosclerosis. It must always be regarded as the main cause when several members of the same family are afflicted with a disturbance of hearing which has developed with the characteristic symptoms of otosclerosis. This is demonstrated by the observations of Körner and Hammerschlag. In the genealogical trees of five families reported by these authors, there were forty-three cases of otosclerosis. Körner goes too far when he bases his opinion on the Weissmann determination theory, and says that otosclerosis can always be traced to hereditary predisposition. The English otologists in particular called attention to the fact that this malady is associated with gout (Toynbee, Buck). Doubts have recently been raised against the theory of an uric acid diathesis as an etiological factor (*Alt. Monat. f. Ohren.*, 1907). It is not infrequently observed as a sequel of constitutional syphilis. Habermann's view, that the osseous disease of the labyrinthine capsule is a sequel of acquired and hereditary syphilis, is rightly disputed by Körner. Its frequent association with ozæna is worthy of notice. The author has often had the opportunity of observing this disease originate during the puerperal state, a fact which is also confirmed by Habermann (*loc. cit.*). Its relation to general arterio-sclerosis (Maupetit) has not been proved. There are a great number of cases, however, in which it is impossible to find any etiological factor. According to Walb,* there is a greater tendency for this peculiar affection to develop in those individuals who are subject to anæmia, mental affections, and nervousness. In young individuals, scrofula and rickets may be looked upon as a cause of otosclerosis.

Occurrence.—Otosclerosis occurs at any time of life, especially in elderly people. Frequently, however, the author has found the symptoms of this disease well marked in young, healthy individuals with a hereditary predisposition; and also in those without a demonstrable hereditary taint. In the hereditary form, the symptoms of this aural affection are often very prominent at ten to fifteen years of age. It appears from his observations that women are more often predisposed to this affection than men.†

Condition of the Membrana Tympani.—In the typical forms of otosclerosis, we find the membrana tympani absolutely normal in appearance. A reddish lustre behind the umbo (Schwartze) is an important, although inconstant symptom, which, according to the author's observations, is produced by a hyperæmic condition of the bloodvessels of the osseous wall of the

* Schwartze's *Handbuch der Ohrenheilkunde.*
† According to contemporary reports on the progressive course of Beethoven's aural affection, the deafness of the great composer was probably caused by otosclerosis.

promontory. Sometimes this rose-red lustre of the wall of the promontory is spread over the entire membrana tympani, and causes it to have an unequal infiltrated appearance, the intensity of which varies. The author found this redness in some cases of advanced deafness and in other cases in which the affection was still in its initial stage. Where this condition of the membrane is found, and there is an advanced progressive disturbance of hearing with a positive Rinne, it may be assumed that we have to do with the nervous, progressive deafness of Manasse; in disturbances of hearing of a slight degree, an otosclerotic process, without the stapedio-vestibular articulation being involved, cannot be excluded. In old individuals the drum membrane is not infrequently found to be dull, lustreless, and atrophic. The external auditory canal is free from secretion, dry and pale.

Subjective Symptoms.—The subjective noises which accompany otosclerosis are the most frequent and troublesome symptom, and it is rare to find patients in whom they are entirely absent. These noises are nearly always continuous, and there is no form of ear disease in which they attain such an intensity as in otosclerosis. According to Zwaardemaker, they often have a high pitch. There are some patients who gradually become accustomed to them, while there are others in whom they cause the most unbearable torture, in spite of their long duration, and in whom they may occasion a permanent state of bewilderment and psychological depression, which robs them of all the pleasures of life. These noises seem to cause the greatest amount of annoyance to nervous, hysterical, anæmic, and poorly-nourished individuals. Those noises which are localized in the cranium are found to be especially annoying to the patient. Where the disturbance of hearing increases, the subjective noises also become more intense. There are instances in which they sometimes continue with undiminished severity after complete deafness has ensued, while in other cases every subjective noise disappears when the power of hearing has been entirely lost. Hyperæsthesia acustica is often noticed in this disease.

Intermittent pains, such as sticking and tearing in the deeper parts of the ear, are rarely complained of, and then only in the beginning of the disease. Otosclerosis is often accompanied by a feeling of heaviness and a tightness in the head, weakness of memory, psychical depression, and attacks of dizziness. Neurasthenia and other forms of neurosis are, in many cases, undoubtedly produced by this aural affection.*

Disturbances of Hearing.—The degree of the disturbance of hearing depends on the amount of obstruction to the conduction of sound at the stapes, and on the changes which have developed in the labyrinth. The progressive loss of hearing is the charac-

* Cp. Cozzolino, *Ueber Otoneurasthenic. Verhandlungen des intern. med Kongresses in Rom*, 1894.

teristic symptom of this form of disease. At first we notice that the hardness of hearing is slight, and it may be years before we find a gradual increase. Atmospheric conditions and changes in temperature exercise only a slight influence upon the power of hearing in this affection, while indisposition, fatigue, mental exertion (Toynbee), over-indulgence in alcohol and tobacco, and diseases of the mind, produce a decided change for the worse, which is sometimes temporary. Intercurrent catarrhs of the naso-pharynx, and catarrhal or purulent inflammations of the middle ear, may occasion a temporary or permanent diminution in the hearing.

The difficulty of understanding speech in ordinary intercourse, which arises during the course of this disease, is just as annoying to the patient as in the catarrhal adhesive processes. As long as the labyrinth is not involved in the process, music and singing can still be fairly well perceived, although the difficulty of understanding speech is quite marked. If, on the other hand, those forms are met with which are complicated with an affection of the labyrinth, musical tones are falsely and confusedly interpreted, so that even musical individuals avoid operas and concerts.*

A symptom known as *paracusis Willisii* is frequently observed in this group of middle-ear affections, and occasionally when the function of the sound-conducting apparatus is impaired through other causes. By this term, we understand that the patients hear better in noises, while riding in trains, autos, etc. and during loud music. Löwenberg and Urbanschitsch attribute this phenomenon to an increased irritability of the acoustic nerve, brought about by a general concussion. The author is of the opinion, however, that this improvement in hearing in noises is due chiefly to a shaking up of the ossicles, whose joints have become rigid; these bones are thus thrown out of their equilibrium, and are thereby rendered more capable of transmitting the waves of sound. The author has also shown that the terminations of the acoustic nerve are simultaneously thrown out of their equilibrium, which causes them to become more easily excited by the waves of sound. He was the first to demonstrate experimentally that in nearly two-thirds of the cases in which there was a hindrance to the sound-conducting apparatus as a result of a middle-ear affection, a more or less striking improvement in the hearing was produced by placing a deep, vibrating tuning-fork upon the cranium. His experiments also showed that this improvement is observed in some cases in which the cranial bones are shaken by a toneless, rapidly-vibrating body, and that it is not necessary to employ bodies having tones in order to produce a similar effect. This proves, therefore, that the tones and noises have absolutely no influence upon the acoustic nerve. His view was, furthermore, corroborated by the fact that *paracusis Willisii* was not observed in those cases of deafness (without middle-ear affection) which were proved to be of nervous origin; this was also confirmed by Roosa (*Arch. f. Otology*, vol. xii., 1883) and Lucae.

In cases in which there is deafness for speech, the perception for the watch and acoumeter through air conduction is correspondingly diminished. The author has only rarely seen cases in which there was a striking hearing distance

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* Cp. Heimann, *Ueber progressiv fortschreitende Schwerhörigkeit. Wiener klin. Rundschau,* 1898.

for the watch when the deafness for speech was quite advanced (Roosa, *Amer. Journal of Med. Science*, 1877). The perception of the lower tones is shortened, and is in accordance with the degree of disturbance of hearing; on the other hand, the tones of Galton's whistle are sometimes perceived nearly to the uppermost limit. Often, however, the upper limit of perception is also reduced (Möller), and tone-gaps are sometimes found when testing with Galton's whistle. In those cases in which the deafness is marked, we find that the perception for the watch (acoumeter) through the cranial bones is reduced or entirely wanting; this is also true when there is a negative Rinne and a lengthened perception through the cranial bones. If the affection is bilateral, a positive result is obtained by Weber's test only when the difference in the hearing power of the two ears is very great. Rinne's test is positive in the beginning of the disease as long as the disturbance of hearing is still of a mild form; when the deafness is far advanced, however, this test, as well as Gelle's, is always negative. This is one of the most important diagnostic signs in the typical form of otosclerosis. With complete loss of the hearing, the results of Rinne's test are often doubtful. In cases in which during the course of the disease there is a gradual diminution for the perception of the watch and acoumeter through the cranial bones and the tuning-fork tests show, besides a negative Rinne, a shortened conduction through the cranial bones, one may conclude that there is a coincident disease of the sound-perceiving apparatus.

Course and Terminations.—Otosclerosis frequently begins with weak subjective noises, which gradually increase in intensity, and often exist a long time without any noticeable disturbance of hearing. They are frequently attributed to a so-called nervous tinnitus, until after the lapse of months or years there is a noticeable decrease in the hearing. Nevertheless, we occasionally meet with cases in which the subjective noises and disturbance of hearing arise simultaneously, or where the tinnitus develops only after the deafness has existed for some time. The affection is usually bilateral; it seldom remains localized in one ear. Where one ear becomes diseased, the other generally becomes similarly affected after several months or years.

The primary symptoms of this disease are usually overlooked, as the patients often become aware of their malady only when they notice a disturbance of hearing in ordinary conversation. The progressive loss of hearing is usually interrupted by pauses of some duration, and shows only slight variations. Still, there are patients in whom the degree of deafness remains stationary for years. Cases are not infrequently observed in which a sudden change for the worse takes place after the deafness has remained stationary for a long time. Sudden explosions and injuries to the cranium may cause a rapid decrease in the hearing or a sudden deafness.

While we sometimes meet with cases of otosclerosis which end in marked deafness after having run a course of many years (twenty to thirty), there are other cases in which the disturbance of hearing increases so rapidly that close conversation can no longer be heard, even after the disease has lasted only for several months. In these malignant forms, the functional tests, as a

rule, show an early complication of changes in the auditory nerve (loss of perception for the watch and shortened perception for the tuning-fork through the cranial bones). This rapid loss of hearing is observed especially in cases of constitutional or hereditary syphilis, scrofula, tuberculosis, and anæmia. A striking change for the worse takes place in women after each puerperal state.

Diagnosis.—The diagnosis of otosclerosis in its typical form is easily established when it is associated with progressive deafness. If, in a case of progressive deafness, the membrana tympani is normal, with or without a reddish lustre from the inner tympanic wall, the Eustachian tube permeable during catheterization, Rinne's test negative, the low tones inaudible, and the perception for the highest tones still present, the diagnosis of the typical form of otosclerosis, with its primary seat in the labyrinthine capsule, can be made with absolute certainty. In the initial stage of the affection, where the deafness is still slight, and where the subjective noises are the prevailing symptom, we cannot say with certainty whether we are dealing with an otosclerosis or with a nervous deafness. In such cases, therefore, if we find a hereditary predisposition, we may suspect otosclerosis.

In regard to the diagnosis of the mixed forms of adhesive processes in the middle ear with otosclerotic changes in the labyrinthine capsule, the author refers the reader to what has already been said on p. 305.

Prognosis.—This is especially unfavourable in the hereditary forms of this disease, in constitutional and hereditary syphilis, and in cases in which the disturbance of hearing develops rapidly; furthermore, where the perception for the watch through the cranial bones disappears at an early stage, where a shortened perception for the tone of the tuning-fork through the cranial bones is manifest while the disease is still in its incipiency, and where there are constant and intense subjective noises. A more favourable prognosis may be given in those cases in which, in spite of the fact that the affection has existed for a long time, the disturbance of hearing is still slight, the perception for the tick of the watch through the cranial bones is preserved, and the perception for the tone of the tuning-fork through the cranial bones is lengthened (lengthened Schwabach).

Treatment.—Considering the anatomical changes in the labyrinthine capsule and the terminations of this disease, our clinical experience has shown that the treatment of the typical forms of otosclerosis is on the whole very unsatisfactory and in the majority of cases unsuccessful.

The local treatment of this disease through the Eustachian tube has proved ineffectual, and in some cases even detrimental. On the other hand, however, pneumo-massage in the external auditory canal brings about a more striking improvement in the

hearing than inflations *per tubam ;* this applies especially to those cases in which the massage is administered in the first stage of the process, and in which the mobility of the foot-plate of the stapes is not yet greatly reduced by bony ankylosis. The massage must, however, be given only from a half to one minute, and 2–3 times a week for a period of 4–5 weeks, after which there must be a rest of several months. The vibrations must follow each other with great rapidity, but their amplitudes must be slight and the motion of the piston must be 1 mm., and not more than 4 mm. In reference to the pressure and duration of the massage, the same applies here as has been said in the chapter on catarrhal adhesive processes (p. 310). If the massage is applied too long and too violently, it causes increased tinnitus and a diminution in the hearing power.

Although the improvement in hearing produced by massage is only of a temporary nature, we must nevertheless consider it of some value, as such a change is very often accompanied by a diminution in the tinnitus and a relief of the troublesome head symptoms. Massage has very little influence on the progress of the disease, and is of no value in the advanced forms in which there is complete ankylosis of the stapes.

The fact that the internal administration of sodium or potassium iodide has proved of value in bone affections induced the author to prescribe sodium iodide ($\frac{1}{2}$–1 gm. per diem) for 25–30 days, 2–3 times a year, in those cases in which the otosclerosis was not yet far advanced. The results were satisfactory in a number of cases in so far as the continued use of the iodides in the above-stated intervals stayed the rapid progress of the disease in those cases in which the disturbance of hearing had not yet attained a high degree. Where, however, the stapes was firmly ankylosed, every therapeutic measure proved absolutely useless. In those cases in which one suspects a syphilitic origin, a Wassermann test should be taken, and, if positive, the usual antisyphilitic treatment should be given. Many drugs, such as sojodin, iodoglydin, phosphorus, thyreoidin, and numerous others, have been suggested for this malady, but up to the present they have yielded no results.

From the author's experience no improvement is brought about by a change in climate, sea-air, and the different bath cures. Such patients feel best at a resort which lies in a protected spot at a moderate height, and where the air is dry.

In reference to the treatment of those cases in which the progressive disturbance of hearing runs its course with symptoms of otosclerosis, and the condition of the membrane, as well as the swelling or stricture of the tube, allows us to assume that there are pathological changes in the middle ear, the same remarks apply here as in the treatment of catarrhal adhesive processes, to which the reader is referred to on p. 307.

Extraction of the stapes, which has been suggested in otosclerosis, is based upon experiments performed by Flourens, Kessel, Ricardo, Botey, Grunert.

Garnault, Faraci, and others, on birds and rabbits; in these animals deafness ensued after the removal of the columella (stapes) from the fenestra vestibuli, and after the escape of the perilymph from the labyrinth. After several days or weeks, however, the lost function returned, and the animals again became sensitive to sound. Anatomical investigations showed that the fenestra vestibuli was again closed by a newly-formed membrane.

Extraction of the stapes is an operation easily performed if the foot-plate is movable in the fenestra vestibuli. But even in these cases fragments of the cartilage, covering the rim of the foot-plate, frequently remain behind.* If, on the other hand, the stapes is partially or totally ankylosed in the fenestra vestibuli, the crura will be fractured even by the most careful extraction. Circumcision and loosening of the ankylosed foot-plate without injury to the labyrinthine contents, which have been proposed for these cases, are seldom successfully carried out, because the plane of the fenestra vestibuli is at such an inclination to the axis of the external auditory canal that the field of operation cannot be entirely surveyed.

In this operation particles of the broken foot-plate may enter the vestibule, giving rise to a suppurative inflammation of the labyrinth, which would destroy the endings of the acoustic nerve.

The technique of this operation is as follows: A perforation is first made in the posterior superior quadrant of the membrana tympani, through which the incudo-stapedial joint becomes visible; the tendon of the stapedius and the incudo-stapedial articulation are then severed, and the stapes is removed with a small, delicate hook.

This operation should always be performed under a general anæsthetic. It is frequently followed by severe dizziness, which disappears within a few days.† In several cases a transient middle-ear suppuration has been observed after the operation.‡

Extraction of the stapes in non-suppurative middle-ear processes, and in otosclerosis, has, from years' experience, proved to be a useless therapeutic measure. In the majority of cases a marked diminution in the hearing, which leads to deafness, follows this operation. Such an unfavourable termination in otosclerosis is not astonishing if we consider the anatomical conditions present, and if we consider that even by the early extraction of the stapes the advancing bone-formation in the labyrinthine capsule and the closure of the fenestra vestibuli cannot be checked.

Extraction of the stapes in non-suppurative middle-ear processes, and in otosclerosis, has been shown to be of no value§ by C. J. Blake,‖ of Boston, under whose supervision the greatest number of stapes extractions was undertaken; Knapp (International Otological Congress in London, 1899), Grunert,¶ and Panse reported similar results.**

It must, however, be mentioned here that extraction of the stapes may

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* The author's experiments on rabbits showed that fragments of the foot-plate of the stapes almost always remained behind in the oval window after the operation of extraction. In one case he saw regeneration of a foot-plate take its origin from the rim which had been left behind.

† Dench, *New York Medical Journal*, 1891.

‡ L. Jack, *Transactions of the American Otological Society*, 1892 and 1893; and *Boston Medical and Surgical Journal*, 1895.

§ In a praiseworthy article (*Practitioner*, May, 1897, p. 494) Cheatle gives a résumé of the views of different authorities on the intratympanic procedures which we are now discussing.

‖ *Transactions of the American Otological Society* (Twenty-sixth Annual Meeting), vol. v., 1893; *Transactions of the International Medical Congress*, Rome, 1894.

¶ *Arch. f. Ohrenh.*, vol. xli., 1896.

** *Die Schwerhörigkeit durch Starrheit der Paukenfenster*, 1897.

occasionally be practised with success after a middle-ear suppuration has run its course, when an entirely different anatomical condition is present. For further particulars, the author refers the reader to the chapter on the Intra-tympanic Operations after Cessation of a Suppuration of the Middle Ear.

II. The Muco-Purulent Inflammations of the Mucous Membrane of the Middle Ear.

(a) Acute Inflammation of the Middle Ear (Otitis media acuta).

Acute inflammation of the lining membrane of the middle ear is characterized by an exudation which develops rapidly, with more or less marked reactive phenomena, and which is at first sero-sanguineous, then muco-purulent or purulent. There is also a simultaneous inflammation of the membrana tympani, and, in addition to this, the affection runs a typical, definite course, which is generally of short duration. The anatomical changes at the beginning of the process are indicated by marked hyperæmia, which is soon followed by exudation into the interstitial tissue of the mucous membrane and into the tympanic cavity. Those cases of acute middle-ear inflammation, which have been examined *post-mortem*, show that the mucous membrane is greatly swollen, tumefied, and ecchymotic in consequence of the interstitial serous effusion, and that the epithelium is cloudy, swollen, raised, and cast off in places. In a number of cases, the author found the spaces in the network of the pelvis ovalis, in the recess of the round window, and in the external attic, infiltrated with plaques of purulent exudate. These pathological changes were also seen to a more or less degree in the mucous membrane of the Eustachian tube, and in the lining membrane of the mastoid cells.

The exudate in the middle ear—which is often so slight in the beginning of the affection that none is seen after paracentesis—is at first of a sero-hæmorrhagic nature; after several days, this is followed by the effusion of a thick, cloudy exudate which is mixed with mucus, pus cells, and blood-corpuscles. The secretion is often composed mainly of pus cells, with only a slight admixture of mucus. The exudate is not always of a thick nature, but is at times so firm and tough that it can be removed from the depressions of the tympanic cavity and recesses of the labyrinthine windows only in the form of a compact mass. The author has repeatedly seen such a condition at *post-mortem* examinations. In some cases, especially in influenza, scurvy, and diabetes (otitis media hæmorrhagica). one finds mainly a hæmorrhagic exudate.

In most text-books otitis media acuta is discussed as a form of disease belonging to the acute sero-mucous catarrhs. If, however, we stop to compare the two, we find vast differences. In the catarrhs, the membrana tympani is only slightly changed, transparent, without injection, or only slightly hyperæmic; the mucous membrane of the tympanic cavity shows only

a moderate congestion. The exudate is a clear serous fluid, or a transparent colloid mass; the reactive phenomena are absent, or present only in a mild form; finally, the disease usually runs a slow course, and requires a long time for the absorption of its exudate. On the other hand, however, in otitis media acuta the membrana tympani is intensely hyperæmic, inflamed, covered with exudate, and completely opaque; the mucous membrane of the cavum tympani is highly congested; the exudate is cloudy, of a mucous character, mixed with numerous pus cells, or entirely purulent; the reactive phenomena arc marked and accompanied by severe symptoms; lastly, the course is rapid, and the exudate disappears shortly after the Eustachian tube has been rendered permeable. Notwithstanding the fact that one disease passes into the other, the differences which we have just enumerated give each disease a peculiar clinical character, which has an important bearing on the treatment to be employed.

Etiology and Occurrence.—The following are the most frequent causes of acute inflammation of the lining membrane of the middle ear: Atmospheric conditions, cold plunges and sea-baths, naso-pharyngeal catarrhs, infectious diseases such as scarlet fever, measles, variola, typhoid fever, influenza, erysipelas, pneumonia, bronchial catarrh, and chronic (sero-mucous) middle-ear catarrh. In addition to these, an acute inflammation of the middle-ear can also be induced by the use of nasal douches, by all naso-pharyngeal injections which are applied with too much pressure, by snuffing up of cold fluids, and by operative procedures in the nose and naso-pharynx, owing to the extension of an infection through the Eustachian tube. Galvano-cauterization of the mucous membrane of the nose may also give rise to an inflammatory condition in the middle ear due to the marked reaction which sometimes follows this procedure.

Acute inflammations of the middle ear are more often met with in children than in adults. In our climate they are seen more often in spring and autumn than in summer and winter. They frequently occur in epidemics of influenza. In the majority of cases only one ear is affected; seldom the two simultaneously, or one after the other.

Condition of the Membrana Tympani.—In the mild forms of this inflammation the membrane appears greatly injected; this is especially noticeable at its periphery, in the region of the short process, and along the handle of the malleus. Those portions situated between the manubrium and periphery present a lustreless gray and stippled appearance, and are also of a yellow colour if there is an accumulation of secretion in the tympanic cavity.*— The radiating arrangement of the blood-vessels is rarely discernible at this stage of the process. Sometimes punctate or diffuse ecchymoses on the membrane are found at the beginning of the affection; this is especially the case in the otitis of influenza.

In the more severe forms, the entire membrane is of a uniform

* Compare Politzer, *Atlas der Beleuchtungsbilder des Trommelfells*, 1896, Plate V., 2.

scarlet-red or livid colour; when, however, the injection is most marked in the mucous membrane layer, the membrane presents a shining aspect resembling a copper-plate. This condition, which lasts only a short time at the beginning, disappears very rapidly, owing to the timely saturation of the external epidermic layer. Through swelling of this layer the membrane assumes a dirty-ash or violet-gray appearance, the epidermis becomes cracked by numerous crossing fissures, the handle of the malleus is rendered invisible, while the short process can be distinguished only as a yellowish-white protuberance in the midst of the grayish-red surface.

The inflammatory infiltration is often confined only to the posterior superior part of the membrane, which (Fig. 153)

FIG. 153.—BLUISH-RED, IRREGULAR SWELLINGS AT THE POSTERIOR SUPERIOR QUADRANT OF THE MEMBRANA TYMPANI—ECCHYMOSES.

Appearance in a man, 47 years of age, fifteen hours after the beginning of the inflammation. Climax of inflammation and subsidence of swelling on the sixth day. Cure after fourteen days.

FIG. 154.—GLOBULAR SWELLING AT THE POSTERIOR SUPERIOR QUADRANT OF THE MEMBRANE; AT THE BOTTOM OF THE SWELLING A YELLOWISH-GREEN EXUDATE IS SEEN SHINING THROUGH, WHICH IS SHARPLY DEMARCATED ABOVE BY A LINE WITH ITS CONCAVITY DIRECTED UPWARDS.

A condition found in a woman, 30 years old, on the second day of the disease. After subsidence of the inflammation the posterior part of the membrane remained thinned.

bulges towards the meatus as a bluish-red, uneven swelling, covering the handle of the malleus, and presenting the appearance of a polyp; the anterior part, which lies much deeper, is often only slightly altered. We sometimes find at the beginning of this affection, just as in acute myringitis, the formation of one or more serous or hæmorrhagic bullæ, which burst after a short time and discharge their contents into the external meatus. The hæmorrhagic bullæ which are found in influenza otitis are situated at the posterior superior segment of the membrane, and are sometimes in communication with a hæmorrhagic vesicle in the auditory canal. Interlamellar abscesses (Eysell) are seldom met with in this form of inflammation. A grayish-yellow exudate in the inferior part of the tympanum, similar to a hypopyon,

can be seen shining through in some subacute cases in which the membrane is still partly translucent. Sometimes there develops on the external surface of the membrane a sero-hæmorrhagic secretion which is of short duration, and causes no disturbance in the continuity of the membrane; or there may be a perforation of the membrane, which is of short duration and is accompanied by a sero-hæmorrhagic discharge; after the closure of the perforation, the disease presents the clinical course of a simple, acute middle-ear inflammation.

A rare and interesting condition of the membrane in acute middle-ear suppuration is the development of exudation sacs on the posterior superior quadrant of the membrane, and communicating with the tympanic cavity. They appear (Figs. 154 and 155) as loose, globular or bag-shaped sacs on the reddened, swollen membrane, and have a greenish or yellowish-gray colour; that they communicate with the tympanic cavity is shown by the fact that the exudate, which is driven by an inflation of air from the tympanum into the sacs, is demarcated by a line from the air in their upper part.

These protruding sacs of the membrane are more often seen in the otitis media acuta of adults than of children. They frequently develop very rapidly on a membrane which was previously normal, and especially in individuals in whom the posterior superior part of the membrane has become atrophic, in consequence of a present or exhausted middle-ear catarrh. In the latter case, atrophy and sinking of the posterior part of the drum membrane, which comes into contact with the incudo-stapedial joint, almost always remain after the acute inflammation has run its course.

FIG. 155.—BAG - SHAPED SWELLING COVERING THE HANDLE OF THE MALLEUS, AND ARISING AT THE POSTERIOR SUPERIOR PART OF THE MEMBRANE. THE LOWER PART OF THE SAC CONTAINS A YELLOW, GREEN CLOUDY EUXDATE AFTER AN INFLATION OF AIR.

A condition found in a young man on the third day of the disease. Cure after three weeks.

Symptoms.—The disease usually begins with piercing, tearing pains in the ear, which radiate towards the vertex, neck, and teeth, and are occasionally preceded by a feeling of fulness in the ear or violent headache. These pains seldom attain such a degree of severity in adults as in children. In the latter, the affection, which is often termed otalgia, or earache, is nothing less than the accompanying symptom of an acute inflammation of the middle ear. The pains are seldom continuous, but intermittent; they increase particularly towards evening and during the night, and again remit in the course of the day. The remissions are more complete in children than in adults. Coughing, hawking, swallowing, and eructation usually cause the pains to increase. Spontaneous pain and tenderness on pressure over the mastoid are met with most frequently in adults during influenza otitis, less often in the primary forms. On the other hand, it is almost always noticed that the region below the auricle corre-

sponding to the Eustachian tube is almost invariably sensitive to pressure. In children, there is very often a great tenderness on pressure over the entire region of the ear. The author has repeatedly seen in adults, an acute middle-ear inflammation complicated with a trigeminal or cervico-occipital neuralgia. If the examination is undertaken in a superficial manner, the latter may be mistaken for a mastoid abscess. The disease often runs its course without fever in adults; occasionally, however, a rise of temperature above 38° C. (100·4° F.), preceded by a chill, is observed in the evenings at the beginning and up to the climax of the process. The high fever (over 40° C. = 104° F.) which occurs in very young children is sometimes accompanied by vomiting, delirium, and convulsions.

The subjective noises, such as ringing, hissing, whistling, and whizzing, which often accompany an acute middle-ear inflammation, are sometimes of an intermittent character. These sensations, as the author was the first to demonstrate on the non-perforated membrane, correspond to visible pulsations of different spots of light, or of a large portion of the bulging membrane. The early subsidence of these noises in the course of the inflammation may be regarded as a favourable sign; if, however, they continue uninterruptedly after the disease has run its course, this must be looked upon as an unfavourable symptom.

In addition to these subjective noises, the patients often complain of a feeling of heaviness and tightness of the head and of the resonance of their own voice. The latter symptom often continues until the inflammation has run its course. Only by testing the sense of taste can we sometimes find an alteration on that side of the tongue corresponding to the diseased ear (Urbantschitsch). The author has seen a slight transient facial paralysis in several cases.

On the border between the exudative middle-ear catarrh and otitis media acuta, the oft-occurring subacute inflammations are found. They run their course with mild, reactive symptoms, without fever, with hardly any disturbance to the general system, but with the discharge of a muco-purulent exudate.* The very cloudy, yellowish-gray membrana tympani, with its depressed umbo and its bulging parts lying between the periphery and handle of the malleus, shows a radiating injection which is usually of long duration. This form, which is characterized by its protracted course, occurs in lymphatic, cachectic, and tubercular individuals. In healthy young persons we find this form as a sequel to an exudative middle-ear catarrh which has lasted a long time.

Disturbances of Hearing.—In the first stage of the inflammation (fluxion), in which the pain increases in intensity, the

* In individuals who died of other diseases, Görke found, strikingly often, at the post-mortem of adults, an inflammatory exudate in the middle ear without a perforation in the drum, and is of opinion that such exudates occur in the last days or weeks of life (*Verhandlungen des Deutsch. oto. Gesellschaft*, 1904).

disturbance of hearing is usually of a moderate degree. It is only in the following stage of exudation that the deafness becomes marked, owing to the accumulation of the exudate in the tympanic cavity, and to the intense swelling of the mucous membrane of the tube and tympanum; the pain diminishes simultaneously in consequence of a decrease in the hyperæmia of the drum membrane.

The perception for the watch or acoumeter through the cranial bones is, as a rule, normal; it may be temporarily reduced or entirely wanting when there is a simultaneous hyperæmia and serous infiltration of the labyrinth, in secondary syphilis, and in phthisical and decrepit individuals. In unilateral affections the tone of the tuning-fork is localized, with only few exceptions, towards the diseased ear.

The auscultation sounds (p. 120) vary according to the nature of the secretion and the degree of swelling in the tube. The thinner the exudate, the more distinctly will gurgling noises be perceived; when the exudate is tough or hard, and when the swelling in the tube is marked, the noises produced by the entering air have a rough, sharp, and irregular sound.

Course, Duration, and Terminations.—The course and duration of an acute middle-ear inflammation depend on the intensity of the process, the cause of the disease, and the general condition of the patient.* The duration of the painful stage in the primary inflammations and in persons of a healthy constitution varies from several hours to eight days and over. As a rule, the pains reach their climax on the third or fourth day, and become less intense with the appearance of the exudate. Repeated exacerbations of the inflammation, with an increase in the pains and in the fever, are not infrequently observed during the course of the disease. When the process runs a regular course, a decided diminution in the hearing takes place with the disappearance of the pains; this diminution, however, is subject to more or less striking fluctuations until the hearing again returns to its normal state.

As the pains abate the diffuse hyperæmia and swelling of the membrana tympani, as a rule, also disappear; the membrane presents a yellow or leaden-gray appearance, the short process of the malleus becomes more prominent, while the manubrium is still covered with the markedly injected bloodvessels. At the same time only a few or a great many sharply-defined bloodvessels are visible on the membrane, which (Figs. 156 and 157) extend as slightly tortuous twigs from the intensely hyperæmic peripheral vessels towards the centre and handle of the malleus. This congestion of the membrane diminishes in proportion to the absorption of the exudate in the tympanic cavity. As the

* According to Kümmel (*Verhandl. des Deutsch. oto. Gesell.*, 1906), the clinical course does not depend alone on the class or virulence of the bacteria, but on the anatomical structure of the diseased middle-ear apparatus—that is, whether we have to do with an epitympanic or mesotympanic type of the affection.

inflammatory process subsides, the lustre of the membrane gradually returns, the handle of the malleus becomes visible. the gray, cloudy membrane gradually clears up, and, as a rule, regains its former normal appearance with the return of the hearing power. Sometimes, after repeated relapses, partial and diffuse opacities, chalk deposits, circumscribed atrophies, and partial retractions remain on the membrana tympani. It is hardly necessary to dwell on the fact that the course is also influenced by a timely rational treatment.

Duration.—If an acute middle-ear inflammation runs a normal course, the parts return to the normal state from a few days (mild form) to three weeks and over. The course of the disease is, as a rule, more favourable in summer than in autumn and winter. When the individuals are healthy and surrounded by favourable

FIG. 156.—RADIATING VASCULAR DE-VELOPMENT ON THE MEMBRANA TYMPANI.

Condition in a man on the eighth day of the inflammation. Clearing up of the membrana tympani and are turn to normal in four weeks.

FIG. 157.—RADIATING VASCULAR IN-JECTION OF THE MEMBRANA TYM-PANI.

Condition in a woman on the ninth day of the inflammation. Membrana tympani normal at the end of the fourth week.

atmospheric conditions, the process runs a rapid course; if, however, the patients are weak or anæmic, or when the affection occurs in the acute exanthemata, in influenza and typhoid fever, or in lymphatic and tubercular individuals, or in association with recurrent otitis media, its course is usually of a protracted nature. Not infrequently painful exacerbations occur in consequence of external harmful conditions, improper diet (alcohol), in erysipelas, in intercurrent naso-pharyngeal catarrhs, and occasionally without any discoverable cause. Such relapses may recur repeatedly, and the author would like to call attention to the fact that particularly in this form of inflammation the disappearance or reappearance of the pain is of prognostic importance, for the reason that a decided lessening of the inflammation can be expected only with a diminution in the pain, while a return of the pain almost always points towards an increase of the inflammatory process. An obstinate tinnitus often remains after influenza otitis: this is due to a simultaneous neuritis cochlearis.

which either disappears after several months or is the forerunner of a progressive deafness.

In the last few years the author has often observed neuralgias occurring in paroxysms after an exhausted influenza otitis, which generally disappeared after the use of salicylate of soda (1 gm. pro diem). A point of tenderness on the parietal eminence is characteristic of these neuralgias (Hammerschlag).

Terminations.—The terminations of an acute middle-ear inflammation are : (1) Recovery without any unpleasant sequelæ. (2) Transition into an acute suppurative inflammation of the middle ear with perforation of the membrana tympani. (3) Transition of the inflammation into the chronic form of exudative catarrh which either subsides or leads to adhesive changes in the sound-conducting apparatus. (4) Extension of the inflammation to the cells of the mastoid process with consecutive formation of abscesses. (5) Extension of the process to the cranial cavity, to the lateral sinus, and to the jugular bulb. These complications, which occur more often in perforative middle-ear suppurations, generally arise without any demonstrable lesion of the bony wall, and are brought about by the emigration of the bacteria through the blood and lymph channels, or along the clefts of connective tissue between the middle ear and the cranial cavity. (6) Death, through general septicæmia arising from the middle ear itself without any diseased condition of the lateral sinus and bulb (otitis media septica).

A tendency to relapse remains for some time after the acute middle-ear inflammation has run its course. We find especially in children that the inflammation recurs regularly for many years in the spring and autumn following a marked coryza or sore throat. Such relapses may end in cure, but frequently, however, if they recur often, they may give rise to a connective-tissue growth in the mucous membrane of the middle ear which impairs the vibratory function of the ossicles and excludes the possibility of restoring the hearing function.

Diagnosis.—The diagnosis is easily arrived at, if one takes into consideration the duration of the disease, the characteristic condition of the membrana tympani, and the general symptoms previously described. It might be possible to mistake it for myringitis acuta only in the beginning of the affection and as long as the disturbance of hearing is still of a mild degree (see p. 258). It is not always possible to state when the inflammation will reach its climax, whether it will subside without any lesion of the membrane, or whether a perforation of the latter will ensue.

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disorders, in diabetics,* and after frequent relapses; furthermore, in persons who cannot avoid harmful external influences during the course of their ailment.

Treatment.—The treatment of acute inflammations of the middle ear is palliative at the beginning. It is our chief aim at this stage to remove or alleviate the pains.

In the milder forms of the disease, accompanied by moderate, intermittent pains, one can bring about a rapid relief by the instillation of 10–15 drops of warm hydrogen peroxide or 10–15 drops of a warm carbo-glycerine solution into the external auditory canal. These are allowed to remain for 5–10 minutes, and repeated every hour or two until the desired relief is obtained. When the pains are severe and appear in paroxysms, they are most rapidly relieved with hot wet dressings of Burow's solution. Relief can also be obtained by the introduction of cotton dipped into 5–6 drops of a very warm narcotic oil (ol. olivarum or ol. hyoscyam. press. 10·0, morph. phtalic. 0·2). Gradenigo and Pes prefer a 1–2 per cent. aqueous solution of carbolic acid to which a 1 per cent. saline solution is added. If the latter proves ineffectual, we may try the instillation of 5–6 drops of a 5 per cent. cocaine solution into the nostril, with the head inclined towards the affected side, by which means several drops of the fluid reach the pharyngeal orifice of the tube.

Sometimes the patients cannot stand warm applications, in which case cold applications often have a surprisingly soothing effect. Bier's stasis bandage, which has been recommended to relieve the pain, has proved of little value. The same is true of Klapp's suction-bell, which has recently been employed. When there is high fever, an antipyretic may be given with beneficial effect.

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The extraction of blood by means of leeches or by the Heurteloup apparatus, which was formerly often employed in acute middle-ear processes, has been discarded. These procedures have no effect on the inflammatory process; still, there are cases in which the severe pains may be reduced or entirely alleviated by their application. For this purpose leeches are applied in front of the tragus. The number of leeches to be used varies from 1 in children to 2–4 in adult, healthy individuals.

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use of alcohol and tobacco forbidden. If the otitis media is accompanied by a sore throat, this must also receive medical attention.

Paracentesis of the membrane (p. 287) is indicated in acute middle-ear inflammations only when, with constant accumulation of secretion in the middle ear, the severe pains continue with or without fever in spite of every local medication. It is further indicated if the otitis media is accompanied by vomiting, convulsions, delirium, and pulsating pains (Brieger), and if there is spontaneous pain or tenderness on pressure over the mastoid process. According to Heimann,* paracentesis should not be performed within the first twenty-four hours, because the transition into a perforative purulent otitis (when such a condition occurs) takes place between the third and fifth day.

By paracentesis the pains are often rapidly relieved; still, they sometimes continue in spite of the fact that the secretion is being discharged. After early paracentesis, there is a sero-hæmorrhagic exudation, which is followed in a short time by a muco-purulent or purulent secretion. If the exudate is thick, the flow of secretion begins only 1–2 days after the operation. In lymphatic, tubercular, and debilitated individuals, the author has often seen a very protracted, chronic middle-ear suppuration with complications develop after paracentesis.

Paracentesis is contra-indicated in the milder forms of acute middle-ear inflammations; for the reason that the author has repeatedly seen, in bilateral affections, a protracted mucopurulent discharge arise in the one ear after this operation, while in the other, in which paracentesis was not performed, he has seen healing and complete restoration of the hearing power take place much earlier by Politzerization.

The disturbances of hearing which accompany acute, middle-ear inflammations are most rapidly relieved by inflations into the middle ear by the author's method. Such inflations are not to be given in the beginning of the process during the painful reactive stage, because the inflammatory irritation and pains are heightened by the sudden increased pressure in the tympanic cavity. As soon as the pains have become less and the hearing has rapidly decreased, we must begin with inflations of air, in order to re-establish the permeability of the Eustachian tube, to remove the exudate in the middle ear, and to facilitate its absorption.

In the great majority of cases, the absorption of the exudate and a complete cure are attained by the inflations alone (comp. p. 104). These should be very light in the beginning of treatment, and increased as the inflammatory process decreases. The author almost invariably administers his method with a sharp act of inspiration in this form of middle-ear inflammation (p. 130).

* *Comptes rendus du XIV. Congr. intern. de Médecine,* Madrid, 1903.

Only when there is a marked resistance in the tube, or when the author's method with the sharp act of inspiration fails, must Politzerization, combined with an act of swallowing, be given forcibly.

The assertion which has been made, that in those cases in which the membrane is intact, infectious particles of mucus are forced from the naso-pharynx into the middle ear during inflations by the author's method, and that an otitis media acuta may thus be brought about, has not been confirmed.

When the membrane is intact, we are not dealing with a direct current of air into the middle ear during inflations by the author's method as in catheterization, but with a condensation of the column of air in the tympanic cavity. It will therefore be seen that the secretion lying in the naso-pharynx or in the ostium pharyngeum tubæ will be pressed only so far into the tube, as the cavity of the middle ear is enlarged through the bulging of the membrane towards the external meatus. The entrance of infectious particles from the naso-pharynx into the tympanum during this method is out of the question even from a physiological standpoint; on the contrary, particles of mucus can reach the middle ear more easily by catheterization.

The use of the catheter is contra-indicated in all those cases in which the air can be forced into the tympanic cavity with sufficient strength by the author's method. By the former procedure the instrument comes into contact with the inflamed mucous membrane of the tube, thus increasing the swelling, and aggravating the inflammation in the tympanic cavity, owing to the mechanical irritation in the tube. It is only in exceptional cases in which the tube is impermeable through marked swelling that we are compelled to resort to catheterization.

The striking improvement in hearing which is often noticed immediately after an inflation of air is again partially lost on the following day if the discharge of the secretion does not abate. We have the right to assume that the exudate is getting less if the improvement in the hearing obtained after an inflation remains constant for twenty-four hours, or, as is sometimes the case, increases during this time. From this time on, the inflations are no longer given daily, but only every other day, later every third day, and finally only once a week, until the tests indicate a normal hearing.

Injections of medicated solutions into the middle ear by means of the catheter are very harmful in this form of inflammation; they not only lengthen the course of the inflammation, but frequently occasion an increase in the exudation and in the inflammatory symptoms.

The naso-pharyngeal·affections accompanying acute middle-ear inflammations must be carefully treated, as they have a direct bearing on these inflammatory conditions.

(*b*) Acute Purulent Inflammation of the Middle Ear.

Acute purulent inflammation of the middle ear is characterized by hyperæmia, which generally arises with marked reactive symptoms, and by swelling and cell-infiltration of the mucous membrane of the middle ear, which rapidly leads to the effusion of a purulent exudate and to perforation of the inflamed membrana tympani. The inflammatory changes in the mucous membrane are on the whole very intense, and the discharge, which is generally very copious, contains a large number of pus-cells. This form of inflammation is therefore differentiated from otitis media acuta only by its different clinical aspect, and by its course after perforation of the drum has taken place.

The pathological changes are almost invariably distributed over the entire mucous membrane of the middle ear. Even in those cases in which there were no symptoms of irritation in the mastoid process during the life of the patient, the author has found a purulent exudate in the antrum and in the cells of the mastoid process at the *post-mortem*. The labyrinth usually remains intact; sometimes, however, the anastomosis between the vessels of the middle and internal ear brings about a marked hyperæmia and serous infiltration, rarely a purulent inflammation, which may run along with or without perforation of the labyrinthine windows; a purulent inflammation of the labyrinth secondary to otitis is, in rare cases, encountered in the infectious diseases.

Etiology and Occurrence.—Acute, purulent inflammation of the middle ear is induced by the same causes as acute middle-ear inflammation running its course without perforation of the membrana tympani. The following are the causes: External atmospheric conditions, colds in the head, acute naso-pharyngeal catarrhs, scarlet fever, measles, small-pox, typhoid fever, diphtheria, pneumonia, influenza, erysipelas, whooping-cough, and the puerperal state. Acute middle-ear suppuration sometimes develops after an injury, as after traumatic ruptures, paracentesis, or other operations on the drum. It may also be due to contusions of the head and of the organ of hearing, to forcible attempts at extraction of foreign bodies from the external meatus, and to scalding and cauterization of the ear. Occasionally it follows the use of nasal douches, sea-baths, and the snuffing up of fluids into the nose.

This form of middle-ear disease occurs more often in children than in adults, and is more frequently met with in the spring and autumn than in the summer and winter. Observations have shown that it appears exceedingly often as a complication during an influenza epidemic. The inflammation is more often unilateral in the primary and traumatic forms, and bilateral in the otitis accompanying scarlet fever, measles, and typhoid fever.

Conditions of the Membrana Tympani.—The inflammatory changes on the drum in acute, purulent middle-ear suppuration, before perforation takes place, are more pronounced than in acute middle-ear inflammation running its course without perforation.

At the beginning of the process, the membrane appears injected at its upper part and along the handle of the malleus, and the osseous meatus is also diffusely reddened. Where the process has lasted only a few hours the entire membrane is often scarlet-red or livid, ecchymotic and swollen, and a serous bulla having a pearly lustre may be seen at the posterior superior segment. In the otitis of influenza the membrane is covered with an exudate or by hæmorrhagic bullæ. The posterior segment is more prominent, covered with cracked epidermis, infiltrated with serum, and occasionally covered with a slight exudate. The light reflexes, which are situated at different parts of the membrane, often show a distinct pulsation before perforation has taken place. Sometimes pulsation of a part of the posterior segment of the membrane is distinctly visible.

In other cases in which, in the beginning of the process, the membrane is diffusedly reddened and livid, a yellow discoloration is seen at its most prominent part; this prominence is usually situated on the posterior segment, and is brought about by the accumulation of pus in the tympanic cavity; or a pointed, yellow elevation may be seen on the posterior segment of the membrane, at which place, perforation usually takes place within a short time.*

Interlamellar abscesses, which appear as yellowish-green prominences the size of a millet- to that of a hemp-seed, and surrounded by a livid area, are of frequent occurrence in this form of inflammation. The failure to observe them clinically is due to the fact that they rupture early in the course of the disease. They are situated either in the posterior segment of the membrane or in the region of the umbo. The author has repeatedly seen them at this place in the otitis media suppurativa of diabetics (Fig. 158).

Rupture takes place either at such an abscess (Fig. 159) or at the most prominent part of the membrane, which is often of a yellowish-green colour. Frequently, however, one is not in the position to determine at which place perforation will take place, even if the examination is made early, as cases have been observed in which the posterior segment was markedly bulged, and perforation nevertheless occurred at the anterior inferior part. The osseous meatus is almost invariably markedly injected and swollen, its cuticular surface occasionally macerated and raised through serous infiltration or through the formation of bullæ (Bing), and the border between it and the membrana tympani obliterated.

* Cp. Politzer, *Atlas*, Plate V., 17-19.

The swelling and protrusion of the posterior superior wall of the meatus, observed during the course of the process, must be regarded as a symptom of purulent inflammation and abscess formation in the mastoid cells.

The condition of the membrane presents a decidedly different aspect after perforation has taken place. The auditory canal is swollen, moist, and covered with a layer of exfoliated epithelial shreds. After the parts have been thoroughly cleansed, the membrane, which is covered with a muco-purulent secretion and macerated epidermis, appears excoriated in parts, intensely congested, livid, flat or irregular, and uneven, and the boundary between it and the auditory canal seems obliterated. The handle of the malleus is almost always invisible, while the short process can only be seen at times. The place of rupture is generally between the handle of the malleus and the tendinous ring; more often, however, anterior than posterior to the manubrium.
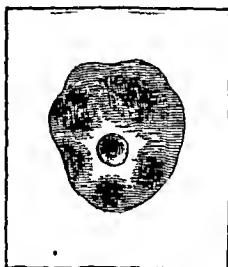
FIG. 158.—ABSCESS, THE SIZE OF A MILLET-SEED, IN THE CENTRE OF THE MEMBRANA TYMPANI SIX HOURS AFTER ONSET OF THE INFLAMMATION.

Perforation of the membrane at this place on the following day. Hearing distance before perforation: Acoumeter $= \frac{1}{3}$ m. Whispered speech $=$ 2 m. Condition in a diabetic patient, 30 years of age.
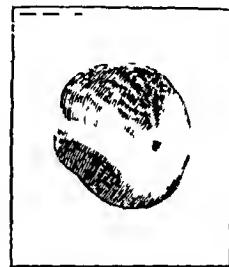
FIG. 159.—NIPPLE-SHAPED BULGING OF THE POSTERIOR PART OF THE MEMBRANE WITH THE PERFORATION ORIFICE AT ITS SUMMIT.

Condition in a woman, 28 years of age, after four weeks' duration of the process. Abscess of the mastoid process. Opening of the mastoid. Five days after the operation the nipple on the membrane disappeared. Cure.

The perforation can frequently not be located, or is indicated only by a small depression filled with secretion and presenting a pulsating light reflex. It often happens that the place of rupture is discernible only when the edges of the perforation are forced apart by an inflation of air into the middle ear, or when a drop of pus appears at the perforation during rarefaction of the air in the external meatus by means of Siegle's speculum. When the discharge is moderate, the perforation sometimes appears as a sharply-defined, black orifice the size of a pin-hole or poppy-seed (Fig. 161), in which a pulsating drop or air-bubble is occasionally seen. As a rule, the membrane is found perforated only at one place. Double or multiple perforations are generally observed

in tubercular individuals (*v.* Politzer's *Atlas*, Plate VI., 8, and Plate VIII., 27 and 28).

The perforation is sometimes situated at the apex of a nipple-shaped elevation, in the posterior part of the membrane; sometimes, during Valsalva's method, a drop of pus can be seen exuding through the opening without a simultaneous escape of air * (Fig. 160). The orifice of the perforation, situated at the apex of the nipple-shaped elevation, forms the place of exit of a canal running into the prominence and communicating with the tympanic cavity. Granulations are not infrequently found in these protuberances. This form of perforation is, according to the author's observations, often combined with inflammation and abscess formation in the mastoid process. The author has also noticed that when such a condition of the membrane is found, the middle-ear suppuration frequently runs an extremely protracted course. The size of the perforation in the acute forms of otitis rarely exceeds that of a hemp-seed; on the other hand, however, we find that in the otitis following infectious diseases, and when a tubercular nodule breaks down, a rapid destruction of the entire membrane and a diffuse loss of substance may take place even within a few days. Perforation of Shrapnell's membrane is rather unusual in acute middle-ear suppurations.

Character of the Secretion.—At the beginning of the affection the secretion does not always appear in the form of pus, but as a red serum, or as a clear yellow, viscid fluid, which assumes a purulent or blennorrhœic character only after a few days. The amount of secretion is very trifling in some cases, while in others the discharge is so profuse that the entire field is again covered immediately after syringing, or after its removal with cotton tampons. During the course of the disease the discharge of thin pus, free from mucus, may follow a blennorrhœic secretion, and *vice versa.* This fact deserves special attention, because, according to the author's observations, the blennorrhœic forms of suppurative middle-ear inflammations always take a more obstinate course than the purulent forms. Hæmorrhagic secretion is met with in cachectic individuals, in leukæmia, in traumatic inflammations (Truckenbrod), in Bright's disease, and in endocarditis after diphtheria. According to Haug (*Deutsche med. Wochenschr.*, 1896), hæmorrhages in the ear appear as an early symptom of nephritis.

The theory of the etiology and pathology of otitis media acuta has assumed a new phase through the bacteriological investigations of the last ten years. It is now the general opinion that this affection is due to bacterial invasion from the naso-pharynx, in that the micro-organisms migrate through the Eustachian tube into the middle ear. From the researches of Zaufal, Moos, Weichselbaum, Rohrer, Chatellier, Gradenigo, Bordoni-Uffreduzzi, Maggiora, Lermoyez, Leutert, Brieger, Nadoleczny, Scheibe, Lauffs, Hasslauer, Kümmel, Süpfle, Neumann, Ruttin, and others, it was shown that this disease is of an infectious nature, and of micro-parasitic origin.† It must, however, be stated

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* Cp. Politzer, *Atlas*, Plate VI., 10-12.

† The complete literature on this subject, up till 1899, is found in Leutert, *Arch. f. Ohrenheilkunde*, vols. xlvi. and xlvii. Of the recent articles must be mentioned à paper by Kümmel (*Bakteriologie der akuten Mittelohren-tzündung*), the reports of Denker, Kobrak, Wittmaack, H. Neumann (*Verh. d. Deutschen oto. Gesell. in Bremen*, 1907), and the monograph of Gomperz (*loc. cit.*).

that the acute inflammations of the middle ear do not owe their origin to any specific bacteria, as various micro-organisms can produce a similar pathological effect.

The *Streptococcus pyogenes* has been shown to be by far the most frequent cause of acute middle-ear inflammation (Kümmel, Süpfle, Neumann, and Ruttin); in children the *Diplococcus pneumoniæ* (Fränkel-Weichselbaum) is also frequently present. In addition to these bacteria, the following have been found in the secretion: The *Staphylococcus pyogenes albus* and *aureus*, more rarely the *Bacillus pyocyaneus*, the pneumonia bacillus (Friedländer), the *Streptococcus mucosus* (Neumann, Ruttin), the *Bacterium coli* (Stern,* Gasser, Siegfried Weiss), the *Meningococcus intracellularis* (Weichselbaum-Jäger) in epidemic cerebro-spinal meningitis (Frohman, Schiff, Netter), the diphtheria bacillus in middle-ear diphtheria (M. Wolf), the tubercle bacillus, the gono-coccus (Haug, Flesch, Reinhard), the typhoid bacillus in the cavum tympani of patients who died of typhoid fever (Preising), and the influenza bacillus (Scheibe). In the middle-ear secretion, the *Streptococcus pyogenes*, the *Diplococcus pneumoniæ*, and the *Streptococcus mucosus*, appear most frequently in pure culture; the staphylococcus mostly as a mixed culture with the *Strepto-coccus pyogenes* (Ruttin, Neumann). Of all the bacteria, the *Streptococcus capsulatis mucosus* generally causes the most virulent forms of middle-ear inflammation, and is usually associated with the greatest amount of destruction. Its virulence is generally manifested by the rapidity and extension of the process, and by its early involvement of the mastoid process.

It is not quite certain what influence the staphylococci exercise in producing a middle-ear inflammation. Some consider them the primary exciting cause, while others regard them only of secondary importance in otitis media purulenta (Pes, Gradenigo).† It is certain that they may replace the primary exciting bacteria in the course of a middle-ear suppuration (Gradenigo, Zaufal, Roskin). Lermoyez and Helme (*Annal. d. mal. de l'oreille*, 1895) came to the conclusion that otitis media acuta is always of mono-bacillic origin. Secondary infection by the staphylococcus takes place only in the later course of the disease, by the entrance of these organisms *per tubam*, or through the external auditory canal.

The views of the different authors vary as to the clinical characters of these various micro-organisms. According to Leutert (*A. f. O.*, vols. xlvi. and xlvii.), the middle-ear suppuration brought about by the *Diplococcus pneumoniæ* is differentiated from that due to the pure streptococcus by its rapid course, its frequent tendency to spread over the entire middle ear, and its frequent complication with mastoid and extradural abscesses. According to the author's experiences, the diplococcus often becomes manifest after a long latent period—in fact, when the middle-ear affection has almost healed. The *Bacillus pyocyaneus* can produce intracranial complications, as Voss proved in one case, by agglutination. Gradenigo agrees with Nadoleczny, that the strepto-coccus is the exciting cause of the severe forms of the true otitis; but according to Nadoleczny this bacterium may also produce the mild forms. Gradenigo and Zaufal think that the pneumococcus is the prevailing bacterium in extradural abscesses. Jacobson (*Lehrb. d. Ohrenheilk.*, p. 182) is of the opinion that the different severe complications of purulent middle-ear inflammations may be produced by any of the micro-organisms which act as the exciting cause of otitis media. Coussien ‡ considers the mono-bacterial infections as the most favourable, from a prognostic point of view. Poly-bacterial—that is, mixed—infection, is, according to him, the main cause for the long duration of the acute suppuration, and for the disease eventually becoming chronic.

The invasion of the pathogenic micro-organisms into the middle ear takes place most frequently *per tubam* from a catarrh in the naso-pharynx (Rohrer,

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* *Zeitschr. f. Ohren.*, vol. xxvi.
† *Arch. f. Ohren.*, vol. xxxviii.
‡ *Annal. des maladies de l'oreille*, etc., 1902.

Morphologie der Bacterien, etc., 1889). Owing to some external harmful influence (catching cold), their entrance into the tympanic cavity is probably favoured by the destruction of the ciliated epithelium in the tube,* the cilia of which wave towards the naso-pharynx and ordinarily guard against infection. The bacteria which have entered the tympanic cavity may remain dormant for a long time, and may even entirely lose their vitality. If, however, some external, harmful influence (cold, trauma, etc.) produces a disturbance in the nourishment of the mucous membrane of the middle ear, its power of resistance to bacterial influence is thereby reduced; this affords an opportunity for the nourishment and development of the micro-organisms which finally bring about an acute, exudative inflammation of the middle ear. According to Moos, the indirect entrance of the bacteria into the middle ear by means of the lymphatics occurs in scarlet fever and in sloughing of the pharyngeal portion of the tube. Less common paths of invasion of the bacteria into the middle ear are: (*a*) Entrance by the blood through the walls of the vessels (hæmatogenic infection), as occurs in endocarditis (Trautmann) and diphtheria (Moos); (*b*) entrance through the perforated membrana tympani (Moos, Walb) from the external auditory canal.

Symptoms.—Acute purulent inflammation of the middle ear begins with piercing, tearing, boring, throbbing pains in the ear, which radiate towards the vertex, occiput, teeth and shoulder, and generally attain a greater severity than in the non-suppurative acute middle-ear inflammations. These pains are always more intense in children than in adults. At times they are preceded by a feeling of fulness in the ear, or by severe headache. A complete remission is seldom observed, as they usually become more intense towards evening and in the night, and generally decrease towards morning to such an extent that the patient may sleep uninterruptedly for several hours. Coughing, sneezing, hawking, swallowing, physical exertion, and mental strain, generally cause a marked increase in the pains. Irritation of the conjunctiva of the corresponding side, œdema of the eyelid, and photophobia may occur; if they do, it is usually in the severe inflammations before perforation of the membrane has taken place. The inflammation is sometimes complicated with facial paralysis, which remains after the suppuration has run its course, or with a trigeminal neuralgia which has been brought about by a simultaneous affection of the Gasserian ganglion. It is still less common to find it complicated with a cervico-occipital neuralgia. Occasionally painful points, especially on the vertex, are found in the course of the trigeminus. Paralyses of the abducens nerve have been reported.

Subjective Noises.—Subjective noises are by no means a constant symptom. They are caused partly by an increased pressure and partly by a simultaneous hyperæmia in the labyrinth. These noises are usually of a pulsating nature, and are experienced as rustling, roaring, hissing, knocking, and hammering. This pulsation frequently corresponds, although

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* Kreidl found from experiments on frogs that the motion of the ciliated epithelium in the tube is from the tympanic cavity towards the pharynx.

not always, to a rhythmical movement visible on the membrane. Autophonia often occurs in this form of inflammation.

Acute purulent middle-ear inflammation is usually associated with high fever, a feeling of tightness in the head, and at times with vertigo and mental depression; sometimes it begins with chills and vomiting.

Severe head symptoms and high fever are generally observed in young children, especially in the otitis arising in the course of an infectious disease.* The symptoms are, as a rule, less violent in adults. Sometimes the most severe middle-ear inflammations run their course without the least disturbance of the sensorium. At other times, however, we find a marked rise in temperature, an increased frequency in the pulse, and an intense feeling of tightness in the head; these conditions are especially observed in otitis media septica,† running its course with pyæmic symptoms. It is rare to find unconsciousness, delirium, convulsions, and arhythmia; when these do occur they pass off very rapidly, and are generally met with in very young children, or as a consequence of brain congestion and meningeal irritation.

Disturbances of Hearing.—The disturbance of hearing is often very slight in the beginning of the inflammation, but as exudation rapidly progresses the deafness soon attains a higher degree. After perforation has taken place, and the secretion has begun to discharge, the hearing distance generally increases slightly; it nevertheless varies continually in the further course of the affection, depending on the quantity of secretion and the increase and decrease of the swelling of the mucous membrane. Total deafness is observed only in panotitis, and in the extension of the middle-ear suppuration to the labyrinth.

The perception for the watch and the acoumeter through the cranial bones is, as a rule, preserved; it is only in exceptional cases that it disappears before rupture, to return again after this has taken place. The same is true of Weber's test. Only in those severe scarlatinal and diphtheritic forms of inflammation occurring in children does the power of perception entirely disappear; this is due to a disorganization of the endings of the auditory nerve, brought about by a simultaneous exudation, or by the immigration of micro-organisms; to opening of the labyrinthine capsule through caries or erosion of the labyrinthine windows, and finally to syphilitic inflammations. Where the affection is unilateral, the tone of the tuning-fork in the Weber test will almost always be lateralized towards the diseased ear. Rinne's test is either negative or yields no positive result.

Course and Terminations.—The course of an acute purulent middle-ear inflammation depends on the cause, the intensity of the process, the constitution of the individual, and on the time at which a rational treatment is begun. In the acute forms, the time which elapses from the beginning of the inflammation to rupture of the membrane varies considerably, and depends partly on the power of resistance of the inflamed and softened membrane,

* See chapter on Otitis Media Acuta in Infants and Children.

† Compare Kümmel, W., *Vom Ohr ausgehende septische Allgemeininfektionen* (*Mitteil. aus d. Grenz. d. Med. u. Chir.*, Jena, 1907); and Dunn, *Archives of Otology*, December, 1906.

to the pressure of the accumulated secretion in the middle ear, and partly on the slow or rapid destruction of the tissue of the tympanic membrane itself. Perforation takes place the quickest in those cases of otitis due to the streptococcus. Although perforation takes place in some cases within a few hours, still we find that it generally occurs only on the third or fourth day, and in protracted cases sometimes not until 2 to 3 weeks. In the infectious forms, especially in the otitis of scarlet fever, measles, and influenza, perforation usually ensues shortly after the beginning of the inflammation.

When perforation takes place, it is sometimes accompanied by the sensation of a bursting blister; as soon as the discharge begins to flow freely, the pains cease immediately or within a very short time. Only in exceptional cases do they continue with uninterrupted severity after perforation has taken place; this is probably due to a simultaneous inflammatory irritation of the periosteal layer of the mucous membrane, or to a coincident abscess formation in the mastoid process. With the commencement of the discharge the fever, as a rule, abates, the head symptoms disappear, and the subjective noises become less. It is often found that the head symptoms and tinnitus continue for a long time with undiminished intensity, and gradually grow less or disappear as the inflammatory process subsides.

· The secretion is usually very copious during the first few days after perforation of the membrane has taken place. At first it is of a sero-hæmorrhagic nature, but after a few days it becomes more opaque and purulent, owing to the admixture of many cell elements. A diminution in the inflammatory process ˙in the acute cases is usually observed in the second week; this is made evident by a gradual decrease in the exudation, which becomes more mucous, and by a diminution or subsidence of the pulsation on the membrane. As the secretion becomes less there is a corresponding improvement in the hearing in consequence of the reduced swelling of the mucous membrane of the middle ear. The secretion, in the last stage of the process, is often diaphanous and mucous in nature. After the discharge has continued for some time it finally ceases, and the perforation, as a rule, closes by newly-formed tissue. Cicatrization takes place either gradually, or so rapidly that the orifice is overgrown in one night, in spite of the fact that on the previous day the discharge was rather copious, and the air was heard to rush through the perforation with a loud rattling noise during Valsalva's method.   •

After closure of the perforation, the membrane appears grayish-red, dull, and only the short process is distinctly visible. The place of rupture is indicated by a yellowish-gray, somewhat retracted cicatrix, towards which several small vascular twigs sometimes radiate from the periphery of the membrane (Fig. 162); frequently, however, the cicatrized part can no longer be dis-

tinguished.   During the further course of the disease, the diffuse redness disappears, radiating vessels become apparent, the malleus becomes visible, and finally the hyperæmia disappears entirely; the lustre and transparency of the membrane return so completely that often no trace of the former inflammatory process is discernible.   In cases in which the perforation is situated at the apex of a nipple-like elevation, a slight prominence often remains on the membrane a long time after the perforation has closured. It is unusual, in the acute forms, for the orifice in the membrane to remain patent after cessation of the suppuration.   Opacities, chalk deposits, cicatrices, and partial atrophies, which often remain in the membrane, are usually not associated with a disturbance of hearing.   As a rule the hearing returns only several
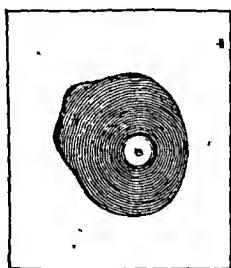
FIG. 160.—PERFORATION, THE SIZE OF A POPPY-SEED, BEHIND THE UMBO, IN THE FOURTH WEEK OF THE DISEASE. FROM A MAN, 65 YEARS OF AGE.

Perforation occurred on the third day. Acoumeter=2 cm.; speech ¼ m.
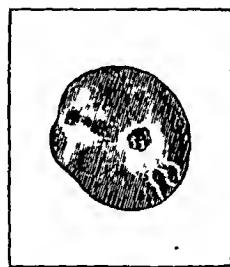
FIG. 161.—CONDITION OF THE MEMBRANE AS IN FIG. 160 AT THE END OF THE SIXTH WEEK.

The otorrhœa had ceased for fourteen days. The perforation is olosed by a yellowish-gray, somewhat depressed cicatrix, to which several small vascular twigs extend from the periphery of the membrane.   Hearing distance for acoumeter=10 cm.; for speech =3 m.

weeks after closure of the perforation, even if the disease has run a normal course; this is always more rapid in summer than in winter.

The duration of the suppuration until closure of the perforation varies in the acute forms from 10 to 20 days.   Cases are occasionally met with in which the discharge ceases even after 2 to 3 days, while in others it continues for several weeks or months.

Acute, middle-ear suppurations arising in the course of scarlet and typhoid fevers, during a severe puerperal state, in influenza, diabetes and erysipelas, in lymphatic, tubercular, and cachectic individuals, when complicated with otitis externa, and in inflammation and abscess formation in the mastoid process, often take an irregular, protracted course.   Those cases also run a protracted course in which the perforation is situated at the apex of a nipple-

like elevation of the membrane (Fig. 160); in which granulations form on the drum membrane and at the borders of the perforation, or on the mucous membrane of the tympanic cavity; and in which there is a prolapse of the mucous membrane of the middle ear through the perforation opening.

The irregular course of the affection is characterized by frequently recurring attacks of pain, by remissions in the temperature, and by an increase in the secretion, which had already become less. The symptoms of exacerbation become more prominent when there is a simultaneous inflammation of the mastoid process, or when an early closure of the perforation takes place. In the latter case, the recurring and often violent pains disappear only when the opening in the drum is re-established by paracentesis, or when the adherent margins of the wound are forced apart by the accumulated secretion in the middle ear. Meningeal irritation, pyæmic fever, delirium, convulsions, and paralysis are occasionally observed in the severe forms of this middle-ear affection.

Terminations.—The terminations of acute, purulent, middle-ear inflammation are: (1) Cure, with complete restoration of the hearing function; this usually takes place within 3–4 weeks, but not infrequently only after several months. (2) Transition of the purulent inflammation into a sero-mucous catarrh after cicatrization of the perforation. (3) More or less disturbance of hearing after closure of the perforation, owing to connective-tissue adhesions in the tympanic cavity. This termination is most frequently noticed in lymphatic, cachectic, or syphilitic persons, or in individuals having a chronic naso-pharyngeal catarrh or ozæna. (4) Permanent disturbances of hearing in consequence of extensive loss of substance in the membrane, with or without caries or exfoliation of the ossicles, or in consequence of a consecutive exudation in the labyrinth, or a panotitis which often completely destroys the endings of the acoustic nerve. These sequelæ occur most often in the scarlatinal and scarlatinal-diphtheritic suppurations of the middle ear. (5) Inflammation of the mastoid cells (see Diseases of the Mastoid Process). (6) Caries and necrosis of the tympanic walls and ossicles, with exfoliation of the same. This outcome is most often observed in the otitis of scarlatinal diphtheria, more rarely in that of measles, typhoid fever, and tuberculosis. (7) Suppuration of the labyrinth in consequence of perforation of the labyrinthine windows. (8) In death with an intact or perforated membrane. Death occurs either from meningitis, extradural abscess, brain abscess, sinus thrombosis, or general sepsis, and finally from erosion of the carotid.* (9) In chronic middle-ear suppuration, which will be discussed in the following chapter.

Diagnosis.—The differential diagnosis between otitis media

* See chapter on Intracranial Diseases of Otitic Origin.

acuta and otitis media perforativa is very difficult in the first
stage of the process.   This is due to the fact that the inflamma-
tion sometimes subsides without perforation, even when the
symptoms are very severe, while, on the other hand, perforation
may take place when the objective and subjective phenomena
are very slight.   We may assume with great probability that
perforation of the membrane is about to take place in those
cases in which there is marked projection of the membrane and
yellowish-green pus can be seen shining through, or in which
the bulging has pointed in the form of a pustule.

After perforation has taken place the diagnosis of acute
middle-ear suppuration may be established: (1) By ocular inspec-
tion, when one either sees the perforation at once or only after air
has been driven through the tympanic cavity.   (2) By the gradual
or rapid appearance of a drop of pus on the membrane at the
place of perforation.   In most cases, the pus may be made to
appear by rarefaction of the air in the external auditory canal by
means of the pneumatic speculum.   (3) By auscultation, where-
by the hissing and rattling of the air can be heard as it passes
through the perforation during Politzerization.   This procedure
is of value especially in those cases in which the perforation is
masked by the bulging of the anterior inferior wall of the meatus,
or in which the membrane cannot be seen on account of the profuse
purulent discharge.   In those rare cases in which the canal
of the perforation passes through the layers of the membrane
in an oblique direction, the air can be forced through the per-
foration more easily when applying low pressure.   (4) By con-
densation of the air in the external auditory canal, whereby the
air escaping through the Eustachian tube into the pharynx can
be heard by means of the auscultation tube, the one end of which
is inserted into the nostril of the patient, the other into the ear
of the physician (*vide* p. 137).   This method is especially applic-
able when inspection of the membrane and auscultation of the
external auditory canal give no results.

Prognosis.—The prognosis of acute purulent inflammation
of the middle ear is on the whole favourable, particularly if the
disease appears in strong, healthy individuals.   The following
may be regarded as favourable prognostic symptoms: Perfora-
tion in the first few days of the disease, rapid subsidence of the
pains, absence of inflammatory changes in the mastoid, the
early decrease in the secretion, and, finally, the steady increase
in the hearing distance while the discharge is still going on.
The prognosis is unfavourable when these acute symptoms con-
tinue unabated and when they arise particularly in lymphatic,
tubercular, and syphilitic individuals, in diabetics, in cachectic,
wasted individuals, in disturbances of the sexual organs, and in
old patients; furthermore, in middle-ear suppurations which
develop in the course of scarlet fever, scarlatinal diphtheria,

typhoid fever and measles, and in chronic empyema of the accessory sinuses of the nose. Complete cure is seldom attained in all these cases, as it is just these causes which favour the transition of an acute into a chronic suppuration of the middle ear.

Symptoms which render the prognosis unfavourable during the course of the disease are: The continuance and frequent recurrence of the pains; the continuance of high temperature, and the undiminished discharge of secretion after the disease has lasted several weeks, which points to the development of a mastoid involvement; further, uninterrupted subjective noises, the rapid destruction of the drum membrane, the speedy enlargement of the perforation, the growth of granulations on the membrane and in the tympanic cavity, the exfoliation of one or more of the ossicles, the appearance of swelling in the osseous meatus, painful swelling on the mastoid, marked infiltration and suppuration of the glands in the lateral region of the neck, and the involvement of the facial nerve. It is extremely rare to observe a cure in cases complicated with pyæmia and metastases, and with symptoms of meningitis, brain abscess, pareses, and paralyses.

Bacteriological investigations made in the last few years have yielded some valuable points in determining the prognosis, as a great deal depends on the character and kind of bacteria found in the smear.

The cases of otitis due to the diplococcus, the pneumococcus, and the *Streptococcus mucosus* have, as a rule, a tendency to heal rapidly in the tympanic cavity, but, during a subsequent latent stage, to extend to the neighbouring parts (mastoid process, sinuses, cranial fossæ, etc.), and there to become acute again.

The virulent cases of otitis due to the streptococcus lead, especially under favourable anatomical conditions, more quickly to intracranial complications. The mixed infections have a tendency towards becoming chronic, according to Leutert, especially when the *Staphylococcus pyogenes* is one of the microorganisms found in the secretion.

Acute Inflammation of the External Attic of the Tympanic Cavity.

Clinical observations have clearly demonstrated that circumscribed acute inflammations can be limited to the upper tympanic space, and especially to that part (p. 31) known as the external attic. The exudate is discharged partly into Prussak's space (Fig. 162, *e″*) and partly into the spaces (Fig. 162, *e, e′*) formed by the folds of mucous membrane between the malleo-incudal body and the external tympanic wall. The accompanying figure, taken from a specimen of a diffuse acute inflammation of the tympanic cavity, presents a clear anatomical picture of an exudation into the external attic. Sometimes the inflammation extends

to the neighbouring posterior pouch of the membrane, in which case the posterior superior quadrant also becomes swollen and bulged.

Etiology.—An isolated, acute exudation into the external attic may be produced by the same causes as an acute otitis media. The author has observed it most frequently during acute nasopharyngeal catarrhs and in the acute exanthemata.

Knapp, who saw its occurrence after sea-baths, states that infection may also take place from the external auditory canal; this view is also corroborated by Walb. According to the author's observations, however, infection takes place in the majority of cases through the Eustachian tube.

Conditions of the Membrana Tympani.—These vary according to the intensity of the inflammatory process. In the milder forms, the superior pole of the membrane, the region of the short process of the malleus, and the bordering part of the upper wall of the meatus are intensely reddened and slightly swollen, while the inferior part of the membrane presents an almost normal appearance. When the inflammation is rather severe the membrana flaccida is bulged, either in the form of a reddened or pearl gray bulla or as a sac hanging from the superior part of the membrane to a point below the umbo (Fig. 163), which rapidly subsides without rupture, or after perforation with the discharge of pus (Fig. 164). Various authorities deny the formation of an acute abscess in Prussak's space; nevertheless, the author has had the opportunity of observing such an abscess in several cases. It appears as a round, yellowish-green bulla the size of a millet-seed, which discharges a small drop of purulent secretion after paracentesis (Fig. 165).*

FIG. 162.—FRONTAL SECTION THROUGH THE HAMMER AND EXTERNAL ATTIC OF THE LEFT EAR, IN A WOMAN, AGED 91, WHO HAD PURULENT MIDDLE-EAR INFLAMMATION DURING THE LAST DAYS OF HER LIFE.

h, Hammer; *a*, External attic; *p*, Processus brevis mallei; *m*, Manubrium mallei; *s*, Membrana Shrapnelli; *e, e'*, Plaques of exudate in the external attic; *e''*, Exudate in Prussak's space. (From a specimen in the author's collection.)

Symptoms, Course, and Terminations.—The symptoms of acute inflammation of the external attic vary according to the intensity of the process. The milder forms are associated with moderate pain, slight subjective noises, and often with a marked feeling of pressure and fulness in the ear. The decrease in the hearing is generally slight even in the severe forms. The author

* Cp. Politzer, *Atlas*, Plate V., 12, 13, 28.

has even seen those inflammations running their course with the formation of bullæ on Shrapnell's membrane subside within a few days with complete cure. Cases in which tumour-like projections develop on Shrapnell's membrane, and in which abscess formation occurs in Prussak's space, run their course with severe reactive phenomena; under these conditions the course is much more sluggish, but even here complete recovery usually takes place within a short time. In rare cases, a disturbance of hearing remains owing to the formation of adhesions between the malleo-incudal body and the external wall of the tympanic cavity. The transition of acute inflammations of the external attic into the chronic forms with perforation of Shrapnell's membrane is occasionally observed.

FIG. 163.—A REDDISH-YELLOW SAC OF EXUDATION HANGING FROM THE UPPER PART OF THE MEMBRANA TYMPANI AND COVERING THE HAMMER.

Condition on the eighth day of the disease in a man, aged 18 years, with the symptoms of an acute otitis media. Otorrhœa began on the ninth day. Acoumeter = 18 cm.; whispering = 4 m.

FIG. 164.—CONDITION OF THE MEMBRANA TYMPANI IN THE SAME INDIVIDUAL ON THE SEVENTEENTH DAY OF THE DISEASE.

Otorrhœa stopped after the sixth day. The sac of exudation has mostly disappeared. The handle of the malleus is partially visible. Acoumeter = 1½ m.; whispering = nearly normal.

Diagnosis.—The diagnosis is based principally on the condition of the membrane, on the slight disturbance in hearing as compared with the suppurative middle-ear process, and on the rapidity with which the disease runs its course.

Treatment.—The treatment of this form of middle-ear inflammation is merely palliative, to relieve the slight pain and congestion of the surrounding tissue. This is most readily accomplished by the instillation of warm drops of hydrogen peroxide or carboglycerine, or hot wet dressings of Burow's solution. If a small quantity of pus should collect, incision may be necessary. When the acute stage is passed, and there is a mild degree of deafness owing to consecutive swelling of the mucous membrane in the tympanic cavity and Eustachian tube, inflations of air may be resorted to in order to re-establish the normal function. When, however, there is a perforation of the membrana flaccida with a

slight discharge of pus, the secretion may be aspirated from the attic by gentle rarefaction of the air in the external meatus; the secretion is then removed with sterilized cotton tampons, and weak solutions of hydrogen peroxide are introduced into the external auditory canal.

Treatment of Acute Suppurative Inflammation of the Middle Ear.—At the beginning of this disease, and before perforation of the membrana tympani has taken place, the treatment is similar to that employed in otitis media acuta. In order, therefore, to avoid repetition, the reader is referred to p. 347.

If the membrane is strongly bulged and displays a yellow colour at a localized spot before perforation has taken place, or if the affection is accompanied by severe pain and fever—in short, by all the phenomena which indicate a retention of pus in the tympanic cavity—paracentesis should be performed as early as possible at the most prominent point, in order to establish free drainage. By this procedure we not only rapidly alleviate the severe pain, but also remove the danger of the inflammation extending to the mastoid region and cranial cavity. When there are symptoms of irritation in the mastoid, even if the membrane is not markedly bulged, and there is no increase in the temperature, early paracentesis not infrequently prevents the formation of a mastoid abscess. It is also indicated when the pains continue with undiminished severity, robbing the patient of sleep, when they are refractory to all local and internal medication, or when symptoms of meningeal irritation develop. It must finally be resorted to if the perforation has closed too soon and there are severe pains and symptoms of pus retention. For the Technic of Paracentesis and Anæsthetizing the Drum Membrane, see p. 287.

FIG. 165.—FORMATION OF AN ABSCESS IN PRUSSAK'S SPACE, WITH BULGING OF THE MEMBRANA SHRAPNELLI, IN A MAN AGED 49, ON THE FIFTH DAY OF THE DISEASE.

Paracentesis; healing after a short time.

In performing paracentesis, special care must be taken that all the layers of the intensely thickened membrane are severed, and that the incision is made sufficiently large. An abundant discharge of sero-hæmorrhagic or purulent secretion soon follows. In cases in which, after paracentesis or after spontaneous rupture of the drum, the pain continues, relief is often obtained by first removing the secretion with cotton tampons, and then instilling 10–15 drops of a warm solution of boracic acid 0·5, muriate of cocaine 1·0, and distilled water 20·0, 3–4 times a day. Pieces of cotton soaked in a dilute cocaine-Burow's solution (arg. acet. Burowii 3·0, aqua dest. s. 30·0, cocain. mur. 0·6), and introduced into the meatus, sometimes prove beneficial. Besides these, hot

fomentations and eventually cold applications, with the internal administration of sedatives or narcotics, may be used. When the secretion tends to stagnate owing to insufficient drainage due to a too small opening in the drum, it must be enlarged. If an inflation is now given, it will be seen that the air and secretion pass freely through the opening which was previously occluded.

In regard to the much-discussed question whether, in acute middle-ear suppurations, the secretion should be removed from the meatus by irrigations or by the dry treatment (with dry tampons, drainage), the author would like to state that both methods are of therapeutic value. Irrigations with a warm antiseptic solution or a sterile saline solution are less irritating than wiping out the meatus with tampons. In cases of acute middle-ear suppurations when there is a scanty secretion, the author prefers, in the beginning, the dry drainage treatment. In cases of otitis with profuse discharge, and in those due to scarlatinal diphtheria and measles, only irrigations should be used. These cannot be dispensed with where, owing to a profuse secretion, it is necessary to clean the ear several times a day.

The number of irrigations with a sterile saline solution, a mild antiseptic solution, or with a weak solution of boracic acid ($27°$ to $28°$ R. = $92°$ to $95°$ F.), depends on the amount of the discharge. After irrigation a cotton tampon is introduced into the meatus in order to protect the skin against the irritating discharge.

The dry treatment is carried out as follows: After removing the secretion with tampons, sterilized strips of gauze or pledgets of cotton dipped into powdered boracic acid are inserted into the meatus, and allowed to remain there until they have become soaked with the secretion, whereupon fresh cotton is introduced.

In order to thoroughly remove the secretion from the middle ear, it must be forced into the external auditory canal by a current of air passing though the Eustachian tube. For this purpose inflations by the author's method during an act of swallowing or during a forcible inspiration are of the greatest service in the majority of cases, for reasons previously stated (p. 130). The therapeutic effect of Politzerization is greater than that obtained by catheterization, which should be employed only in those cases in which there is marked resistance in the tube, as experience has shown that the swelling and secretion in the middle ear are increased by the repeated application of the catheter. The use of catheterization in cases in which air passes into the middle ear by Politzerization is absolutely contra-indicated. As a rule, the air-douche is begun on the third to the fifth day after the discharge has made its appearance; at first weak pressure should be used, and increased as the secretion and inflammatory process gradually diminish. In the majority of cases, a striking improvement in the hearing and a subjective feeling of relief are obtained with the air-douche. When there is a coincident naso-pharyngeal catarrh, and an accumulation of secretion in the naso-pharynx, it is advisable, before giving the air-douche, to clean the post-nasal space with an antiseptic spray.

By means of this simple method of treatment we are very often able, in the acute forms, to bring about a complete cure within a few days. Where, in spite of the cessation of inflammatory reactive symptoms, no decrease in the secretion is noticed, treatment with medicaments is indicated.

Although the advances made in the treatment of affections of the ear are very encouraging, still opinions vary as to the treatment of otitis media suppurativa acuta. While some consider local treatment begun as early as possible as the best method of procedure in order to avoid dangerous complications and destructive changes in the ear, others regard the air-douche, syringing of the ear, and medicinal treatment as most detrimental measures, and condemn all local treatment in acute middle-ear suppuration. The good results obtained by most otologists with this form of treatment demonstrates clearly its value, inasmuch as, by the mechanical removal of the stagnant secretion from the middle ear and by a suitable antiseptic treatment, the duration of the disease is not only shortened, but serious complications are prevented in the majority of cases.

Boracic acid when used alone or in combination with peroxide of hydrogen, has proved the most serviceable medicament in acute suppurative inflammations of the middle ear. It has an advantage over the astringents, in that it decidedly shortens the time of treatment. It diminishes the amount of secretion by its antiseptic properties without causing any irritation to the diseased tissue.

Before beginning the treatment with boracic acid, one may use with advantage, hydrogen peroxide for several days after perforation of the membrane has taken place and after cessation of the pains. Having forced the secretion into the external meatus by means of an inflation of air, it is syringed out or removed with cotton plugs; the canal is then filled with a warmed solution of peroxide and allowed to remain ten minutes. The effect of this treatment is often astonishing, as the secretion ceases within 3 to 4 days and the perforation closes.

When the discharge does not become less after using the hydrogen peroxide for several days, the author begins treatment with boracic acid. Having given an air-douche and having syringed or dried out the meatus, the external auditory canal is filled with a solution of peroxide, and with the head of the patient bent to the opposite side, an inflation of air is again given according to the author's method. After this, the auditory canal is again dried out, and a small quantity of boracic acid is insufflated with a suitable powder-blower into the meatus, so that the membrana tympani is covered over with a thin layer of powder. Where the secretion is thick, this method of treatment may be detrimental, as it may cause a clogging of the orifice in the drum, and a subsequent retention. When this is the case we must dispense with the insufflation of powder for a few days until a free discharge has been re-established.

The external meatus is then closed with cotton, and the powder

is allowed to remain in the ear until the following day. If the powder is moistened through, peroxide is again instilled and boracic acid insufflated.. In mild cases, the use of boracic acid alone is sufficient. This treatment is continued until the powder remains entirely dry for twenty-four hours. In such cases it may be assumed that the suppuration has ceased. Astringents are to be used only in those cases in which the treatment with peroxide and boracic acid fails (zinci sulph. 0·2 : 20·0, plumb. acet. 0·1 : 20·0; 15–20 drops to be instilled twice a day, and allowed to remain for a quarter of an hour). In recent years good results have been obtained with the suction apparatus, in that the purulent secretion is aspirated from the middle ear. By this means the pus is not only drawn from the middle ear, but also from antrum and cells in the mastoid region. Some authors claim that this method of treatment tends to cleanse the tympanic cavity more thoroughly, and thereby hasten the process of healing. In addition to the drugs already mentioned, several newer preparations, such as neutral acriflavum, in solutions of 1–500 to 1–10,000, and mercuro-chrome in 1 to 3 per cent. solutions, have been lately used. Some men have claimed to have obtained good results, while others have seen no advantage in their use. Aniline dyes, such as gentian violet, in various strengths have not proved very satisfactory. The various silver preparations, as silver nitrate, neosilvol, argyrol, etc., are sometimes very beneficial.

The injections of warm sterilized water or a weak (1 per cent.) solution of boracic acid into the middle ear through the catheter is a method of treatment which has given excellent results in obstinate acute suppurations of the middle ear (*vide* p. 123) which have lasted weeks or months. This method, which was recommended by Saissy, and later by Millingen and Gordon, is of great service in those cases in which there is a copious discharge from the middle ear accompanied with a perforation of the membrane, where, in other words, it may be assumed that the canal of the Eustachian tube is markedly affected at the same time. It is also of value in those obstinate forms in which the perforation is situated on a nipple-like elevation of the membrane. The effect of this mode of treatment is often surprising, as sometimes, immediately after the injection, there is a subjective feeling of easiness and a marked diminution of the suppuration within a few days. In cases in which, after the injection, the patient complains of pain, the treatment should be discontinued. Where the perforation in the membrane is too small, we must enlarge it before syringing through the tympanic cavity *per tubam*. By enlarging the aperture the unpleasant incidents (increase of the pain, dizziness) are avoided. The use of Bier's hyperæmic treatment in acute middle-ear suppurations will be referred to in the chapter on Acute Mastoiditis.

Granulations which develop on the margins of the perforation and on the mucous membrane of the middle ear during the course of acute middle-ear suppurations, and which do not disappear under the boracic acid treatment, can either be removed with a snare (having previously applied either a 5–10 per cent. cocaine solution, or powdered cocaine by means of a moistened probe dipped into the drug), or destroyed by the repeated application of liquor ferri sesquichlorati or a 10 per cent. trichloracetic acid solution. After the acute symptoms have disappeared, the granulations may be made to shrink by instillations of alcohol in progressive strengths up to the concentrated solution. Perforations at the apex of nipple-shaped elevations may also be made to close rapidly by the application of trichloracetic acid.

The painful inflammations of the mastoid process which arise during the course of acute middle-ear suppurations, and the symptoms of an intracranial complication, especially the occurrence of certain changes in the fundus of the eye, deserve special consideration.

After the perforation has closed and the discharge has ceased, all local treatment can be suspended. We now limit ourselves to the use of the air-douche by the author's method to overcome the disturbance of hearing. These inflations are given daily in the beginning of treatment, later every other day, and if the hearing steadily improves only once or twice a week until the tests show a complete return to the normal. Some cases of disturbance of hearing which cannot be relieved by treatment disappear after a change of climate, or after a sojourn of several weeks in a mountainous region.

Owing to the predisposition towards relapses, it is recommended, by way of prophylaxis, that, after an acute middle-ear suppuration has run its course, the external meatus be protected with cotton against cold and windy weather, and the use of vapour-baths, head-douches, as well as ducking one's head under water when taking a bath, must be prohibited. The treatment of naso-pharyngeal affections accompanying acute middle-ear suppurations require special attention, as they have an important bearing on the course of the middle-ear condition. The peculiarities of purulent middle-ear inflammations arising in the course of infectious diseases will be discussed in another chapter.

Otitis Media Acuta in Infants and Children.

The frequent occurrence of middle-ear inflammations in infants and young children has greatly aroused the interest of the otologist and the pediatrist. The numerous conditions found by anatomical investigations in addition to the clinical observa-

tions and publications of v. Tröltsch,* Wreden,† Wendt‡ and Kutscharsianz,§ Ponfick (*Berl. klin. Wochenschr.*, 1897), Aschoff (*Zeitschrift für Ohrenheilkunde*, 1897), Gomperz,‖ Heerman (*Bresgen'sche Sammlung*, 1898), Kossel (*Charité-Annalen*, 1893), Göppert (*Jahrbuch für Kinderheilkunde*, N.F., vol. xlv.,) Rasch (*ibid.*, vol. xxxvii.), Hartmann (*Verhandlungen d. deutschen. otologischen Gesellschaft*, 1895, and the *Moscow Congress*, 1897), Siegfried Weiss¶ and Preysing,** and many others, have materially assisted in clearing up the views regarding this form of aural disease occurring in the early years of childhood. The author's investigations on a large number of cases which died in the Caroline Children's Hospital, of Vienna, together with the clinical histories, demonstrated the following pathological conditions:††

Pathological Changes.—These vary according to the intensity of the inflammation, and one therefore finds numerous grades, ranging from simple catarrh to the severe cell-infiltration in the purulent forms.

In nearly all the cases, a cloudy serous exudate, or a gelatinous, sticky mass infiltrated with pus-cells, is found in the middle ear; a true purulent exudate is seldom seen. The mucous membrane is either partly or entirely swollen, œdematous, uneven and glandular.

The microscopic examination of the mucous membrane (Fig. 166) shows large and small hemispherical tuft-like elevations, upon which the epithelium is preserved in parts. Those parts of the mucosa corresponding to the embryonic mucous membrane cushion are greatly thickened; the upper vascular layers are infiltrated with numerous mononuclear and polynuclear leucocytes. This cell-infiltration diminishes to such an extent in the deeper layers of the mucous membrane that the structures lying in contact with the bone appear almost normal (Siegfried Weiss). This layer of mucous membrane, which is free from infiltration, presents a structure, as Siegfried Weiss shows, similar to that of the embryonic mucous membrane. The bone itself shows no changes, with the exception of an accumulation of round cells in the marrow spaces of the spongy tissue. Bacteriological examination of the secretion, of the superficial layers of the mucous membrane, and of the bloodvessels (Weiss), shows the same micro-organisms as those found in otitis media acuta (Kossel, Weiss, Preysing).

It is principally the pneumococci which have been found to be the cause of otitis media neonatorum, less often the streptococci; in primary and secondary tubercular inflammations, the tubercle bacillus. Flesch has shown that the middle ear becomes infected with gonococci during parturition. According to Gomperz, the endemic form of grippe, which is not caused by bacilli, can be differentiated from pandemic influenza only by bacteriological examination.

Etiology and Occurrence.—Exudations in the middle ear of infants and young children are mainly observed in pronounced

* *Verhandlungen d. Phys. med. Gesell. in Würzburg*, vol. ix., 1859.
† *Monatschrift für Ohrenheilkunde*, 1868.
‡ *Archiv für Heilkunde*, vol. xiv., 1873.
§ *Archiv für Ohrenheilkunde*, vol. x., 1876.
‖ *Monatschrift für Ohrenheilkunde*, 1897.
¶ Ziegler's *Beitr. zur patholog. Anatomie*, etc., vol. xxvii., 1900.
** Wiesbaden, 1904, Bergmann.
†† Politzer, *Über. anatom. Veränder. in Gehörorgane bei Otitis med. in Kindesalter. Hauptversamml. der österr. oto. Gesell.*, June, 1900.

cachexia, in broncho-pneumonia, bronchitis, chronic intestinal catarrhs, and in the course of acute and chronic infectious diseases. Their frequent occurrence in measles has been shown by the *post-mortem* examinations of Tobirtz,[*] Rudolphi,[†] and Bezold.[‡] Weiss found changes on the drum membrane in more than half of the children affected with measles; these changes were characterized by hyperæmia, cloudiness, and bulging of the central part of the
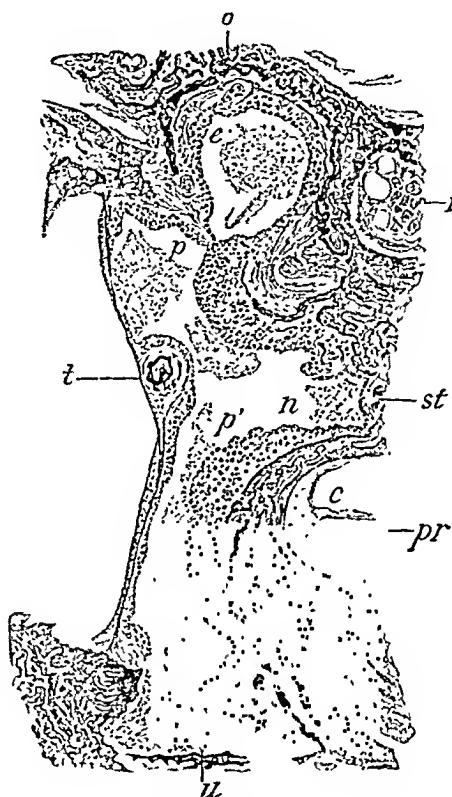
Fig. 166.—Frontal Section through the Tympanic Cavity of a Child who died of Measles.

o, Superior; *u*, Inferior wall of the tympanic cavity; *t*, Membrana tympani with section of handle of malleus; *n*, Recess of fenestra vestibuli; *pr*, Promontory; *c*, Cochlea; *f*, Facial nerve; *st*, Base of stapes; *p*, Inflammatory infiltrated mucous membrane of the attic, adherent to the inner wall; *p'*, Inflamed and swollen mucous membrane of the promontory; *e*, *e'*, Exudate in the tympanic cavity. (From a specimen in the author's collection.)

membrane, which undoubtedly pointed to an exudative process in the middle ear, often running its course without symptoms. In an epidemic of measles, Nadoleczny[§] found that nearly all the children who were attacked during the first few years of life

[*] *Archiv für Kinderkr.*, 1887, vol. viii.
[†] *Zeitschrift für Ohrenheilk.*, vol. xxviii., 3.
[‡] *Münchener med. Wochenschrift*, vols. x. and xi., 1896.
[§] *Jahr. für Kinderheilk.*, vol. lx., No. 12.

were affected with an otitis media. Gomperz maintains that grippe is the most frequent cause of otitis in infants. After this, the next most frequent form of otitis is that occurring in measles and whooping-cough; it is less often met with in diphtheria and chicken-pox, and very seldom after scarlet fever, owing to the fact that this disease occurs rarely in young infants. That in infants infection may also take place from the external meatus has been confirmed by the observations of Pins,* who noticed that otitis media acuta was brought about by the entrance of water into the external auditory canal while bathing the children. According to Pins, attacks of coughing and vomiting during whooping-cough must also be looked upon as frequent causes of otitis in children, inasmuch as during a marked act of expiration mucus is forced into the middle ear. The embryonic character of the mucosa, which still exists during the first years of life, may be regarded as a predisposing cause for the frequent diseased condition of the mucous membrane of the middle ear in infants (Siegfried Weiss).

While Aschoff considers the otitis of the new-born as a 'foreign body otitis,' brought about by the entrance of liquor amnii and mucus into the tympanic cavity during parturition—which, according to the investigations of Gomperz, is limited to the first two weeks of life—Hœrman is of opinion that otitis media occurring during the first years of life, and designated by him as 'concomitant otitis,' must be sharply defined from the primary form, and that it is a sequela to a general disturbance in nutrition and loss of weight. According to this author, the concomitant otitis media rarely leads to spontaneous perforation of the membrane, while the primary form almost always does so. The two forms cannot, however, be easily differentiated, as they may have the same terminations and complications (empyema of the antrum, meningitis, pyæmia).

In the later period of childhood naso-pharyngeal catarrhs, combined with hypertrophied tonsils and adenoid vegetations, give rise to the catarrhs and acute inflammations of the middle ear (Beckman, *Verh. d. deutsch. otolog. Gesellsch.*, 1895; J. Pollak, *Wien. med. Presse*, 1902).

The otitis media of infants is, in the majority of cases, produced by the invasion of the micro-organisms *per tubam* (Weichselbaum); it is seldom occasioned by infection through the blood-channels, and when this is the case it is most frequently observed in tubercular infection. Its frequent occurrence with naso-pharyngeal catarrhs, adenoid vegetations, pneumonia, and bronchitis may be attributed to the fact that the middle ear of children lies in closer relation to the naso-pharynx than in adults, on account of the shortness and width of the Eustachian tube. It is quite evident, therefore, that a catarrh of the respiratory tract may more easily affect the middle ear of children than that of adults.

* *Jahrb. f. Kinderheilk.*, vol. xxvi.

Kutscharsianz examined the ears of 230 children, between the ages of several days and seven months, and found that the membrana tympani was normal in only thirty cases. Fifty showed signs of catarrh and 150 of a purulent inflammation. The same is true of the reports of Schwartze, who found secretion twice in the middle ear of five deceased new-born infants, and of v. Tröltsch, who discovered a similar condition in 62 per cent. of children in the first months of life. According to Hochsinger (who observed that the severe forms of middle-ear inflammations run their course with perforation of the drum membrane much oftener in infants), coryza syphilitica neonatorum leads less often to a perforative middle-ear inflammation than the coryza due to grippe; this may be explained by the fact that the hereditary syphilitic rhinitis of infants principally affects the anterior portion of the nose.

The investigations of E. Weil on the ears of 5,905 school-children showed that the frequency of middle-ear affections decreased steadily with the advancing age of children, but as they grow older they are still more prone to this affection than adults. He found aural affections or their sequelæ in the following proportions: In children 7 years of age, 23·6 per cent.; of 8 years, 23 per cent.; of 9 years, 23·3 per cent.; of 10 years, 17 per cent.; of 11–13 years, 20 per cent.; at the age of 14, only 11 per cent.; and from here to the 18th year, only 2·7 per cent.

Symptoms, Course, and Terminations.—The observations of Göppert, Heerman, Siegfried Weiss, and others, show that otitis media infantum very often runs its course without any apparent symptoms; this applies to a large number of children affected with catarrhs, to ill-nourished children, to those having a muco-purulent nasal discharge, and even to the infectious diseases. In such cases, the only aids in establishing a positive diagnosis are the conditions found on the membrane, such as hyperæmia at the handle of the malleus and at the periphery, radiating injection of the vessels, cloudiness and yellow discoloration, and finally bulging of its central portion. If examination of the infant is done in a perfunctory way, and the ears are not examined in every case, these changes may be easily overlooked. Such children are irritable, display a poor appetite, are restless and sensitive to pain when the region around the ear is touched, to which they often place their hands; the temperature may be only slightly increased and the peri-auricular lymph-glands may be swollen. Ponfick observed gastro-intestinal disturbances before the symptoms of the otitis became manifest.

In other cases in which the infants are otherwise healthy, the affection often appears suddenly with restlessness, constant crying, tremor of the lower jaw, continuous rubbing of the occiput against the pillow, and high fever (39·5° to 40° C. = 103·1° to 104° F.). Where the affection is unilateral, the child often becomes quiet only when laid on the affected side. In accordance with this, Pins and Meissner state that such an infant usually takes only one breast, as the pain is increased when the position is reversed. It is often found that where one ear is diseased, the children allow their head to hang towards the affected side, and pull at that ear during the pain. The pain often comes on in paroxysms,

and increases especially during the night. The remissions which follow these paroxysms of pain are often so complete and extend over a lapse of hours that the children appear perfectly normal.

In children who are in the first years of life, the head symptoms in otitis media acuta often reach such a degree of severity before perforation of the membrane has taken place that the affection, which frequently arises with high fever, vomiting, unconsciousness, and convulsions, presents the picture of a meningeal affection or an acute exanthem beginning with brain symptoms.* These cerebral symptoms may be attributed to a hyperæmia of the numerous anastomotic branches lying between the bloodvessels of the tympanic and cranial cavities in the ununited sutures.

If in such cases we neglect to examine the ears, we become aware that the cerebral symptoms are due to an affection of the ear by the appearance of a purulent secretion from the ear, and by the simultaneous disappearance of the severe symptoms.

The practitioner must always keep this fact in mind, and one must never neglect to thoroughly examine the ears in every child in whom the affection begins with fever and cerebral symptoms.

The disease shows a striking change after spontaneous rupture of the membrane or after paracentesis. The pains suddenly stop, the fever disappears, and the patient falls into a deep sleep, which often lasts for hours. If the otitis is complicated with symptoms of cerebral irritation, convulsions, and unconsciousness, it will be seen that these also disappear. In infectious diseases, a rise in temperature up to 40° C. (=104° F.) often lasts a long time after the appearance of a discharge from the ear. The symptoms of purulent otitis which develop at the crisis of an acute infectious disease are hidden by the symptoms of the general disease, and the aural affection is thus sometimes overlooked, becoming evident only by a marked rise in temperature.

If examination of the drum before perforation has taken place is rendered difficult by swelling of the external auditory canal and by loosening of its epidermis, it will be found that the difficulty of such an inspection is even heightened after perforation has ensued. In such cases the canal, which is already narrowed, becomes so constricted through swelling of its lining membrane and maceration of its epidermis that it is seldom possible to see the perforation. Occasionally one sees contractions of the muscles supplied by the facial nerve, while a complete paralysis of the facial nerve is rare; paralysis of the abducens is still rarer.

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* Streckeisen (*Bericht über das Kinderspital in Basel*, 1864) has shown that purulent catarrh of the tympanic cavity with a meningitic beginning is a cause of cerebral symptoms in pneumonia, and Steiner (*Jahrbuch für Kinderheilk.*, 1869) designated, as one of the main causes of brain symptoms in the so-called brain pneumonia, a coincident purulent middle-ear inflammation.

A general septic infection in the otitis of infants has been observed by Cozzolino and others, but is on the whole rather rare (*Riv. d. clin. pediatr.*, Anno ii.).

Otitis media acuta, with or without perforation, shows a great tendency to frequent relapses in children up to their twelfth to fifteenth year, and especially during a cold in the head and during cold, damp weather. The repeated disinfection of the naso-pharynx with cleansing sprays proves beneficial at times in preventing such relapses; nevertheless, especially in chronic affections of the naso-pharynx, the otitis often returns at varying intervals in spite of this precaution.

In reference to the termination of otitis media infantum, the reader is referred to what has been previously said on p. 359. There is no doubt that catarrhs and purulent inflammations of the middle ear, with or without perforation, heal spontaneously. It can also be laid down as an established fact that some cases of disturbances of hearing, which arise in the later years of life, are the result of an overlooked or neglected aural affection in childhood. As a catarrh and a mild otitis are often due to diseases of other organs, and frequently run their course with slight symptoms, it is essential that the physician should never omit to examine the ears in every disease of childhood.

It has already been mentioned that the purulent otitis of children arising in the course of infectious diseases—as in scarlatinal diphtheria and measles—often has an unfavourable termination in consequence of extensive destructive changes in the middle ear, and its complication with a panotitis. In these cases, the severity of the infection often produces marked changes around the labyrinthine windows with secondary changes in the nerve endings, causing a disturbance in the hearing of varying degrees. This deafness may be trivial or may be so marked that the patient has almost a complete loss of function. In addition, these cases are often associated with extensive destruction of the drum and with exfoliation of one or more of the ossicles. Still, the author has often seen cases in which, in spite of the severity of the infection, both labyrinthine windows remained intact, and in which, in spite of total destruction of the membrane, a hearing distance of 8–10 m. and over for whispered speech was retained after suppuration had ceased.

Considering the large number of aural affections in children, abscess formation in the mastoid process is, according to Gomperz, relatively rare, inasmuch as the conditions for the flowing-off of the pus are more favourable than in adults. An acute empyema often becomes manifest as a periosteal abscess; this develops very easily owing to the fact that the serrations of the fissura petrosquamosa remain open for a long time. When a true acute mastoid abscess has formed it becomes evident by the profuse, often hæmorrhagic, muco-purulent discharge; the rapid reappear-

ance of the secretion in the meatus after removal; the nipple-, club- and mushroom-shaped granulations in the mucous membrane of the tympanic cavity; and the glandular swellings at the angle of the jaw. If the case is chronic, there is also a terrible fœtor of the profuse otorrhœa, concomitant swelling of the meatus, and in rare cases a paralysis of the facial nerve. These symptoms often indicate that an extensive destruction has taken place, thereby exposing the dura and sinus to a varying degree.

There is no doubt that the otitis media which arises in the early years of life has an important influence on the general health of the child. Hartmann* found that in infants a gastro-intestinal disturbance and a loss of weight could be brought about by an exudation in the middle ear, and that the condition improved after removal of the secretion by paracentesis. He furthermore noticed that the rise of temperature which develops in the course of intestinal disturbances could be greatly heightened by the appearance of a middle-ear inflammation. From these facts one becomes convinced of the importance of examining the ears in all infantile gastro-intestinal disturbances combined with a rise of temperature and loss of weight.

The same principles mentioned in the previous chapters are, on the whole, applicable to the treatment of the catarrhs and middle-ear inflammations of infants (*vide* pp. 307, 347, and 364). In reference to inflations of air *per tubam,* it must be mentioned that this method of treatment alone is quite sufficient to bring about a cure in those disturbances of hearing caused by the so-called tubal middle-ear catarrhs. The occasional application of inflations with weak pressure is also indicated in acute non-perforative and perforative otitis, but only after the disappearance of the acute reactive phenomena. Politzer's method is especially serviceable in the suppurative forms to remove the stagnant secretion from the middle ear, and to bring about an improvement in hearing. The author has never seen any evil result follow the rational application of the air-douche in children.

Experience has shown that Politzerization is indispensable in restoring the normal hearing function in the later stages of the disease. It is furthermore evident that patients treated in childhood by Politzerization possess, in later years, normal hearing, while a large percentage of cases which run their course under similar conditions, and are not treated with inflations according to the author's method, suffer from disturbances of hearing ranging from a mild deafness to an almost complete loss of the auditory function.

In the suppurative inflammations of the middle ear, when the drum is red and bulging, paracentesis is indicated in order to create free drainage. If the discharge is scanty, the ear can be cleansed several times a day by gently wiping out the canal and

* *Zeitschrift f. Ohrenheilk.,* vol. xxxiv.

instilling 8–10 drops of a warm peroxide solution, which is allowed
to remain in the ear for several minutes and repeated every three
or four hours. This treatment is continued until the discharge
has ceased and the reactive symptoms have disappeared. Where,
on the other hand, the discharge is copious, it is necessary to
irrigate the ears with a warm antiseptic solution every three or
four hours until there is a diminution in the secretion, whereupon
we can again resort to the instillation of warm peroxide. In
cases in which there is evidence of a slight mastoid involvement,
gratifying results are sometimes obtained by applying a small
ear ice-bag over the mastoid region. This should not be used
continuously, but alternatingly half an hour on and one hour off,
otherwise one is apt to produce a dermatitis. By this procedure
many cases are arrested which would otherwise develop into a true
mastoid abscess necessitating operative interference. In swelling
of the external canal, which in some cases extends over the mastoid
region, one may gain the false impression that one is dealing
with a true mastoid if the examination is done in a perfunctory
manner. In such cases it is well to apply warm wet dressings of
Burow's solution in the canal and over the entire ear, which are
changed every two hours until the swelling has subsided. By
this procedure we are usually able to arrive at a differential
diagnosis, for if the swelling does not respond to this mode of
treatment within a few days we can be certain that we are
dealing with a true involvement of the mastoid bone. It is,
therefore, well in the majority of cases to give these swellings
an opportunity to resolve, unless they are accompanied by severe
symptoms such as sharp rises in temperature, restlessness, etc.

A true mastoid is recognized by redness, œdema, and swelling
over the mastoid region, with or without enlargement of the
cervical glands in the neck. Temperature in infants and young
children is not a constant symptom, and one cannot place too
much reliance upon it, for one often sees cases in which there is
comparatively little external evidence of a mastoid, and there are
marked fluctuations in temperature; while, on the other hand,
there may be a most extensive destruction of the mastoid cells, with
virtually no rise in temperature at all, or only to a slight degree.
That cerebral complications are comparatively rare in the young
may be explained by the fact that the cortical layer of the mastoid
is soft and yielding, so that the suppurative process has in the
majority of cases the tendency to point outwards. When a true
mastoid has developed, local treatment is of no avail and operative
interference is imperative. Inasmuch as the infant mastoid is
not fully developed, it is comprised of one or more large cells
which are broken down and filled with soft bony tissue and
purulent matter. In considering the anatomical structure of the
infant mastoid, one should remember that the antrum is large
and readily laid open, so that a free communication with the

middle ear is easily established. It must also be remembered that the middle cranial fossa during the first years of life lies very low, so that in operating on infants one must not begin too high up, as one may easily enter this cavity. As the skin is very tender in infants and young children, an eczema may easily develop on the aurical and surrounding area during the course of an acute and chronic suppuration of the middle ear, so that it is well to protect the parts once or twice a day with vaseline or some other soothing ointment. The treatment of aural conditions in children over five years of age is the same as in adults.

(c) Chronic Purulent Inflammation of the Middle Ear.

Syn. : Otitis media suppurativa s. perforativa chronica.—Chronischer, eitriger Ohrcatarrh (v. Tröltsch).—Chronische Mittelohreiterung.—Chronic suppuration of the middle ear (Roosa).—Chronic purulent inflammation of the middle ear (Burnett).—Otite profonde de l'oreille moyenne (Bonnafont).—Otite media piogenica a forma chronica (De Rossi).

Chronic purulent inflammation of the middle ear is one of the most important diseases of the organ of hearing, on account of its frequent occurrence and the disturbances of hearing caused by it. Its significance is, furthermore, intensified by the serious complications which may arise in its course through extension of the suppuration to the cranial cavity and sinuses.

In no form of inflammation of the middle ear does the auditory apparatus undergo such extensive changes as in chronic suppuration. The suppurative process not only extends over the entire middle ear, but often involves the external meatus, labyrinth and walls of the tympanic cavity.

Pathological Changes.—In chronic middle-ear suppuration the epithelium of the mucous membrane of the tympanic cavity often loses its ciliated character. The author has, however, seen cases in which the hypertrophic mucous membrane was covered with several layers of very long, cylindrical, ciliated epithelium, in spite of the fact that the suppuration had lasted for many years. The epithelium of the tympanum assumes an epidermic character, especially when the epidermis of the external meatus invades the middle ear (*vide* Cholesteatoma). In microscopic sections, portions of the mucous membrane appear entirely free from epithelium, while other portions are overgrown with an extensive growth of epithelium, which is several layers thick, often pigmented and hornified in its superficial strata, and infiltrated with fat globules.

The most important change of the mucous membrane in this chronic affection consists of general thickening, which is due to an excessive infiltration of round cells and to the dilatation and new formation of bloodvessels. Although the periosteal layer of the mucous membrane is pathologically altered, it nevertheless almost always remains intact, and the subepithelial layer becomes so compressed through round-cell infiltration that it is replaced by a suppurating granulation surface which is traversed by dilated, tortuous, partly new-formed vessels. The mucous membrane appears, therefore, dark

and yellow-red, several times its original thickness, smooth or glandular, and covered with very minute irregular or fungiform excrescences (Fig. 167, z, z′); it is frequently so thickened that it completely fills the pneumatic spaces of the middle ear, the lateral concavities of the tympanic walls, and occasionally the greater part of the cavum tympani. The author was also the first to call attention to the pathological change of the dilated lymph vessels in the deeper layers of the mucous membrane in chronic suppurations of the middle ear; they appear as varicose, constricted vessels, ending in club-like blind pouches, and possessing small branches which form an anastomosing network (Fig. 168).

Another condition which was first described by the author, and which is of no less importance, is the formation of cysts in the hypertrophied mucous
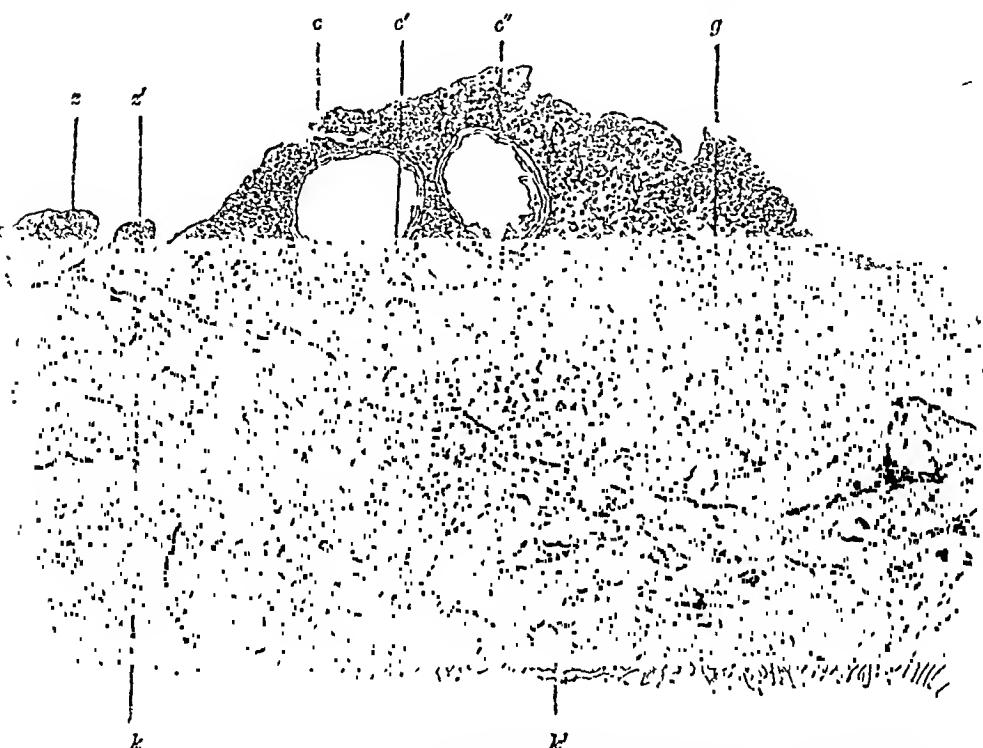
FIG. 167.—HYPERTROPHY OF THE MUCOUS MEMBRANE IN OTITIS MEDIA SUPPURATIVA CHRONICA. FROM A MAN, AGED 19, WHO HAD MIDDLE-EAR SUPPURATION ON THE RIGHT SIDE SINCE CHILDHOOD, AND WHO DIED OF ACUTE OSTEO-MYELITIS.

k, $k′$, Cross-section of the osseous wall of the promontory, with excessively dilated vessels and osseous spaces; g, The greatly thickened and infiltrated mucous membrane of the promontory—the formation of vessels in its deeper parts; z, $z′$, Villous growth on the surface of the mucous membrane; c, $c′$, $c″$, Cystoid spaces in the excessively developed mucous membrane; $c′$, Lamellar piece of epithelium in the cyst.

membrane; they probably are due to constriction of the saccular lymph-spaces in the deep layers whereby they become isolated (Fig. 168), while those in the superficial layer of the granulation tissue are often lined with epithelium (Fig. 167, c, c′, c″), and are formed by the growth of the papillary excrescences, inasmuch as the depressions between them become entirely shut off.*

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* Cp. Zeroni, *Beitrag zur Kenntniss der Heilungsvorgänge nach der operativen Freigelung der Mittelohrräume. A. f. O.*, vol. xlv.

The changes which the diseased mucous membrane undergoes in the course of chronic suppuration of the middle ear are as follows: (1) The growth of round cells may disappear through fatty metamorphosis and degeneration; when the suppuration has even been mild, but of long duration, the mucous membrane hardly ever assumes its normal state, as is the case after an acute inflammation of short duration. (2) Circumscribed elevations develop through partial hyperplasia of the infiltrated mucous membrane; these appear in the form of granulations or pedunculated new growths, which are known as polypi of the tympanic cavity. (3) The formation of a firm connective tissue which resembles cicatricial tissue, and which is developed by the transformation of the round cells into bands of spindle cells; this tissue is found in the middle ear in the form of diffuse tendinous thickenings of the mucous membrane, or as bridges and thick scars, which lead to abnormal adhesions between the membrana
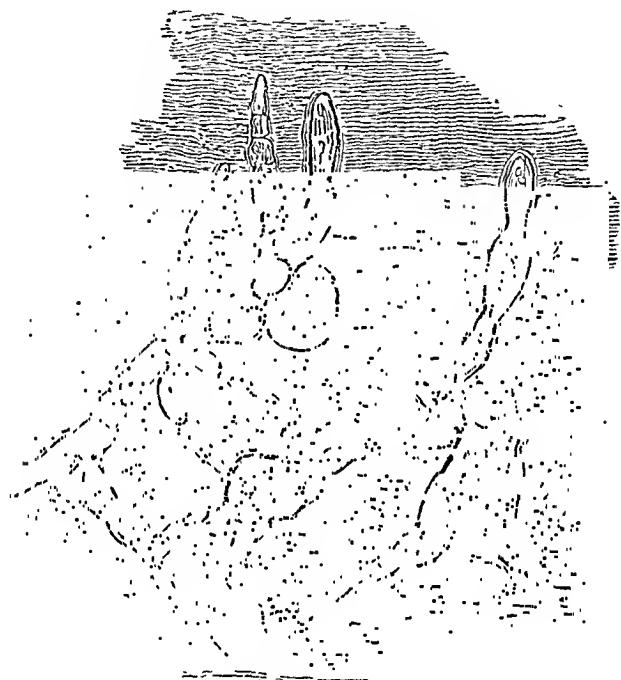
Fig. 168.—Dilated Network of Lymphatic Vessels in the Deeper Layers of the Covering of the Promontory in a Phthisical Person, 27 Years Old, who had Otorrhœa since Childhood. (Right Ear.) (Hartnack, Obj. 7.)

tympani, ossicles, and tympanic walls. Such connective-tissue growths may either remain as such or they may shrink, become sclerotic, calcify, and ossify, or, as is less often the case, the entire mucous membrane may become atrophied. There is no doubt that in many cases the thickened bridges and folds take their origin from threads and folds which are found in variable quantity in the tympanic cavity under normal conditions (see p. 35). (4) The suppurative process may lead to ulceration and destruction of the mucous membrane, which may be destroyed to the bone, whereupon the ulceration may involve the bone itself. (5) The mucous membrane may undergo an epidermal desquamation owing to the inward growth of the epidermis of the external auditory canal into the tympanic cavity, which leads to the formation of cholesteatoma in the temporal bone. Through total destruction or degeneration of the capsular and check ligaments of the ossicles they become so loosened

that they are thrown off; this, however, is most frequently seen in the diphtheritic and scarlatinal suppurations of the middle ear.

These changes in the cavum tympani just enumerated may develop independently at different periods of the process, or they may exist simultaneously. We may, therefore, find in the same ear granulations on the mucous membrane, firm organized connective tissue or cholesteatoma, and in other places ulcerations which reach to the bone.

The membrana tympani undergoes many changes in chronic suppurations of the middle ear. While in acute suppurations—excluding the rapid destruction of the membrane in middle-ear diphtheria, and tuberculosis of the membrane—there is only a disturbance in the continuity of the membrane, in the chronic forms there is a true loss of substance brought about by the breaking down of the tissue.

The destructive process, as a rule, affects the intermediate portions of the membrane—that is, those parts lying midway between the periphery and the handle of the malleus. Even in those cases in which the loss of substance is very extensive, the author found in a large number of specimens that the peripheral portion of the membrane usually remains in the form of a sickle-shaped ledge, which is not always formed by the annulus tendinosus, but by the very compact, peripheral, circular, fibrous bundles of the membrane itself. The part of the membrane which is not destroyed becomes thickened either through the excessive growth of the mucous membrane layer, with or without the formation of cysts, or through a general papillary or polypoid hypertrophy of its cutis layer (Fig. 169); the substantia propria either remains unchanged or becomes partially or wholly supplanted by exudate, chalk deposits, or by the growth of the connective-tissue elements of the neighbouring layers.[*]

Fig. 169.—Villous Growths on the Cuticular Layer of a Perforated Membrana Tympani. From a Tubercular Man, who died in the General Hospital from Secondary Meningitis Basilaris, and who suffered for many years from a Profuse Suppuration of the Middle Ear.

a, Proliferating cuticular layer, with villous projections; b, Substantia propria; c, Mucous membrane layer.

After the suppuration has run its course the edges of the perforation become covered with a layer of epidermis, and the orifice in the membrane either remains patent or is closed by delicate, thin cicatricial tissue in which the elastic fibres of the substantia propria are lacking. The remnant of the membrane is either thickened through the formation of connective tissue or calcified, ossified, and atrophied, and its inner surface may be either free or more or less adherent to the inner tympanic wall.

The mucous membrane of the Eustachian tube is swollen and raised during the period of suppuration, the acinous glands are enlarged, the acini and their ducts dilated, and the epithelium is lacking or stratified. It is rare to find granulations or polypoid degeneration of the mucous membrane of the tube. In the majority of cases, a moderate narrowing of the lumen of the tube remains after the suppuration has run its course; a marked dilatation owing to atrophy of its cartilage and bony walls is seldom seen.

The pathological changes in the mastoid process will be discussed in a special chapter.

The bony walls of the tympanic cavity, which are covered with mucous membrane, show no decided changes in a great number of cases. Not infre-

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[*] Cp. Politzer, *Atlas der Beleuchtungsbilder des Trommelfells*, p. 25, Fig. 14.

quently, however, one finds the bone cells bordering on the mucous membrane infiltrated with round cells, and the vascular spaces dilated—in a word, we find inflammatory changes in the bone more or less developed. This leads either to a condensation of the osseous tissue, to hyperostoses and formation of osteophytes, or to destruction and atrophy of the bone, and finally to caries and necrosis of the temporal bone and ossicles, with all the sequelæ with which we shall become acquainted in the further course of this chapter.

The histological changes in otitis media suppurativa of children are, according to the author's investigations, characterized by papillary growths. The predisposition to these formations can be explained by the papillary growth of the mucous membrane which occurs so often in the new-born. The author has frequently found not only pedunculated papillary excrescences, but ridge and comb-like elevations on the mucous membrane of the middle ear, which ran on the inner wall from the posterior part of the cavity towards the tympanic orifice of the Eustachian tube. These comb-like excrescences are not infrequently located upon elevated bony spines which arise from the walls of the tympanic cavity (Fig. 170).

Sometimes the tightly compressed growths are so abundant that they completely occlude the lumen of the tube. They are most markedly developed on the promontory, at the head of the stapes, on the tendon of the tensor tympani muscle, and on the inner surface of the membrana tympani in the region of the handle of the malleus. All the cells of the mastoid process are filled with granulation tissue, and the antrum contains a plug of exudate composed of pus-cells.

In other specimens taken from children who had died of scarlet fever and diphtheria, the author found the attic filled with hypertrophied mucous membrane, which embedded the malleus and the body of the incus. In addition to this, both recesses, especially that of the round window, were filled with granulations in which the folds of mucous membrane and their ramifications were found; these originated from the pad of mucous membrane in the foetal state,- and formed the bases of these growths.

In cases of scarlatinal diphtheria,

FIG. 170.—SECTION THROUGH THE ANTERIOR PART OF THE TYMPANIC CAVITY OF A CHILD, 2½ YEARS OF AGE, WHO HAD A CHRONIC MIDDLE-EAR SUPPURATION AFTER AN ATTACK OF SCARLET FEVER.

o, Superior; *äu*, External; *u*, Inferior; *i*, Internal wall of the tympanic cavity, covered with polypoid growths; *p*, Pediculated papillary growths; *k*, Section of a bony spine with papillary growths. (From a specimen in the author's collection.)

the author found the malleus-exfoliated and the incus adherent to the inner tympanic wall.

The hypertrophied mucous membrane and the papillary excrescences are composed of round cells, which reach to the periosteal layer of the mucous membrane. The bone, bordering immediately on the diseased mucous membrane, is often only slightly altered; sometimes a very vascular granulation tissue is found in the adjoining bone spaces. The most striking changes are noticed in the structure of the hammer and incus, in that their bone spaces are widened and filled with round cells; these changes are evident even in

those places where no direct connection can be established between the granulation tissue on the inner surface of the membrana tympani and the bone spaces of the hammer. The surface of the papillary growths is covered with a very abundant ciliated or non-ciliated cylindrical epithelium, which is sometimes higher than the normal epithelium of the mucous membrane of the middle ear.

Etiology and Occurrence.—The transition of acute suppuration of the middle ear into the chronic form is caused partly by general and constitutional diseases—as lymphatic diathesia, tuberculosis, syphilis, anæmia, and marasmus—and partly by local changes in the ear itself and by diseases of the naso-pharynx. The cases of otitis media which are brought about by the infectious diseases, and which pass most frequently into the chronic form, are those arising during the course of scarlet fever, diphtheria, more rarely typhoid fever. The chronicity of this disease is also greatly influenced by unfavourable atmospheric conditions and by improper bodily nourishment. It has already been previously shown that this affection does not always arise from the acute form, but may also develop without reactive phenomena in certain forms of cachexia. There is also no doubt that an acute suppuration of the middle ear may become chronic from a neglected or faulty treatment.

The following are the most important local causes which may aid in prolonging the course of a middle-ear suppuration: (1) The granulations and polypoid growths of the mucous membrane of the tympanic cavity and on the membrana tympani, which develop in the acute stage. (2) The retention and caseation of the purulent secretion in the lateral concavities of the tympanum, in the depressions of the petrous bone, and in the cells of the mastoid process. (3) Caries which is developed in the mastoid or in another portion of the temporal bone during the acute course of the disease. (4) Chronic inflammations of the external meatus if the process has extended from here to the middle-ear, as is sometimes the case in erysipelas and chronic eczema. (5) Chronic affections of the mucous membrane of the naso-pharynx and accessory nasal sinuses.

Chronic suppuration of the middle ear occurs more often in children than in adults. Experience has demonstrated that a great number of the purulent processes met with in adults date from childhood.

Character of the Secretion.—The secretion of this form of inflammation is mainly of a purulent or blennorrhœic character; occasionally a transparent colloid mucus is found which contains only a small amount of pus-cells. The quantity of the discharge is sometimes very profuse, but at times so slight that it dries up as dark green crusts in the meatus and in the tympanic cavity. The exudation is most marked in the scarlatinal-diphtheritic forms, in cases of extensive granulations in the middle ear, and in carious processes of the temporal bone. The yellowish-green colour of the secretion is often greatly changed by the addition of cerumen, detritus, blood, micro-organisms (bluish-green discharge), and drugs. When the discharge is thus

altered it presents a reddish-yellow, brown, dirty gray, or black discoloration. In cases of caries it is often very thin, having the character of flesh rinsings, and very irritating. The secretion of chronic purulent inflammations of the middle ear contains, in addition to the pyogenic micro-organisms, putrefactive bacteria and vibriones. According to Lauffs,* one finds, in marked fœtid suppurations which are complicated with intracranial affections, the *Proteus vulgaris* alone, or associated with streptococci, staphylococci, or diplococci. The penetrating offensive odour which is often associated with the secretion is due to the destructive action of putrefactive bacteria, and to the presence of saprophytes. This is not always a symptom of caries, as it occurs not only in neglected cases, but also in those cases in which the ear is most carefully cleansed. In the latter cases the author has observed that this fœtor, which cannot be overcome, is due to some irritating secretion or degenerated cholesteatoma having its seat in some lateral concavity of the tympanum which cannot be reached by syringing; such a continued evil odour of the discharge may, therefore, be an indication for opening up the middle-ear spaces.
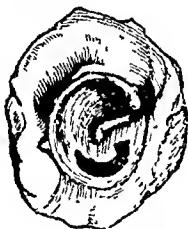
Fig. 171.—Semilunar Perforation in the Anterior Inferior Quadrant of the Right Membrana Tympani.
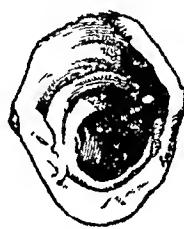
Fig. 172.—Heart-shaped Perforation in the Right Membrana Tympani.

Condition of the Membrana Tympani.—The appearance of the membrana tympani in chronic middle-ear suppuration is so variable that we must limit ourselves to the description of its main types. A correct judgment as to the condition present is all the more important in this form of inflammation, because we can often locate the seat of suppuration in the middle ear by the position of the perforation in the drum.

In those cases in which inspection of the membrane is prevented by the accumulation of secretion in the deep parts of the meatus, it must be washed out with warm irrigations or removed with small cotton plugs. Dried masses of secretion must be loosened with a probe and then removed with forceps.

In the examination with the speculum we must note the location and size o fthe perforation, the condition of the remnant of the membrana tympani and inner tympanic wall, and finally the simultaneous changes in the external auditory canal.

The perforation is most frequently situated at the anterior inferior and posterior superior quadrants of the membrane; the

* *Archiv f. Ohren.*, vol. lxx.

pars flaccida situated above the short process of the malleus is less often destroyed.

The size of the perforation varies from that of a pin-hole to total destruction of the membrane. It does not depend on the duration or intensity of the suppurative process. The greatest

FIG. 173. — LEFT MEMBRANA TYMPANI PERFORATED IN THREE PLACES.

loss of substance is observed in the scarlatinal-diphtheritic middle-ear suppurations, and in the tubercular ulcerations of the mucous membrane of the tympanic cavity.

The form of the aperture is generally round or oval, elliptical, rarely semilunar (Fig. 171), or angular. Perforations situated below the handle of the malleus assume a decided heart or kidney shape, through projection of the handle into the orifice (Figs. 171, 172, 174). The contour and size of the opening vary greatly by reason of the changeable thickness of its margins. Where the discharge is profuse small perforations are hardly visible, and their location is recognized only by a depression with a pulsating light reflex, or by the appearance of pus during condensation of the

FIG. 174.—A LEFT-SIDED, KIDNEY-SHAPED PERFORATION IN A WOMAN, 20 YEARS OF AGE, WHO HAD SUFFERED FOR THREE YEARS FROM CHRONIC MIDDLE-EAR SUPPURATION.

The mucous membrane of the middle ear is dark red, and the congested membrane is covered here and there with gray epidermis. Hearing 'distance: Acoumeter = 25 m. Speech = 65 cm.
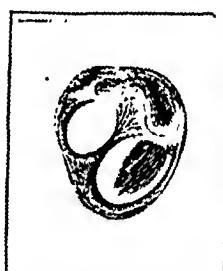
FIG. 175.—DOUBLE PERFORATION FORMED BY A BRIDGE OF THE MEMBRANA TYMPANI ADHERING TO THE PROMONTORY. EXHAUSTED MIDDLE-EAR SUPPURATION IN A WOMAN 23 YEARS OF AGE.

air in the external meatus. Perforations in the anterior inferior quadrant of the membrane are often hidden by the bulging anterior wall of the meatus, and are discovered only by the presence of air-bubbles at the anterior inferior part of the field of vision, brought about either by the condensation of the

air in the middle ear, or by the rarefaction of the air in the external meatus.

As a rule, there is only one perforation in the membrane; still, one occasionally finds, especially in tubercular middle-ear suppurations, two (Figs. 175, 176, 177) and three (Fig. 173) apertures, which vary in form and size. Cases are quite rare in which the membrane is perforated in four or more places, or in which it is pierced like a sieve by numerous small holes; this latter condition is met with in diphtheritic and tubercular suppurations of the middle ear.*

During the time of suppuration the remnant of the membrane appears white, greenish-yellow, or reddish-gray, owing to the epidermis accumulated upon it, or to an interstitial exudate; although it is uniformly reddened, it can, nevertheless, be
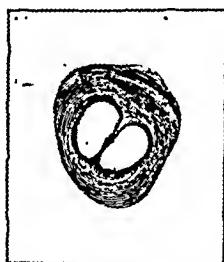
FIG. 176.—DOUBLE PERFORATION IN A MAN, 37 YEARS OF AGE, WHO HAD SUFFERED FROM OTORRHŒA FOR MANY YEARS.
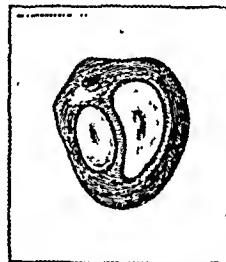
FIG. 177.—LEFT-SIDED DOUBLE PERFORATION IN A GIRL, 17 YEARS OF AGE, WHO SUFFERED FROM A CHRONIC MIDDLE-EAR SUPPURATION SINCE CHILDHOOD.

distinctly differentiated in the majority of cases from the mucous membrane of the tympanic wall, which is either dark red or covered with epidermis and exudate, and from which it often stands out by a distinct shadow. The cuticular layer is seldom excoriated. The margin of the orifice is either covered with secretion or bounded by a red line, and occasionally overgrown with small papillary excrescences. It either remains free, or here and there comes into immediate contact with the inner tympanic wall. Such adhesions are frequently the cause of chronic suppurations, as the pus, from different parts of the tympanum, which has become encapsulated through these adhesions, is prevented from flowing off. It most frequently happens that the posterior margin of the perforation rests against the promontory, while the anterior part remains free, and throws a shadow upon the inner tympanic wall, which lies deeper. In a few cases, in which the periphery of the remnant of the membrane was free, the author saw a whitish or reddish band extend to the inner wall of the cavum tympani (Fig. 178). Where the per-

* Politzer, *Atlas d. Beleuchtungsbilder,* Plate VIII., 17-28.

foration is small, the handle of the malleus can rarely be distinguished on account of the swelling of the cuticular layer; in cases of large perforation, on the other hand, in which the mem-
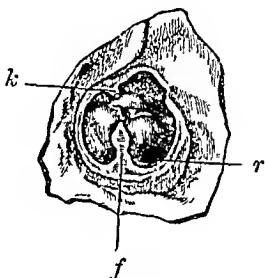
FIG. 178.—LARGE DEFECT OF THE MEMBRANA TYMPANI.

k, Short process of the hammer with the stump of the handle; *f*, Tongue-shaped remnant of the membrane adherent to the promontory; *r*, Fenestra rotunda. (From a specimen in the author's collection.)

FIG. 179.—DESTRUCTION OF THE INFERIOR HALF OF THE MEMBRANE, WITH EXPOSURE OF THE PROMONTORY AND RECESS OF THE ROUND WINDOW. FROM A MAN, 24 YEARS OF AGE, WHO HAD SUFFERED FROM OTORRHŒA SINCE CHILDHOOD.

The inferior end of the handle of the malleus destroyed through necrosis. Hearing distance: Acoumeter $= \frac{2}{3}$ m. Speech $= 2$ m.

brane surrounding the manubrium is destroyed, it either protrudes freely into the orifice in its original form and position (Fig. 180), or it appears several times its normal thickness, drawn inwards, its inferior extremity in touch with the inner tympanic wall, or its lower end shortened through carious degeneration (Fig. 182), or entirely absent (cp. Politzer, *Atlas*, Plates VII. and VIII.).
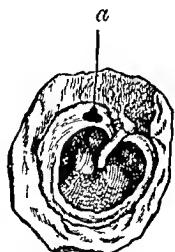
FIG. 180.—EXTENSIVE LOSS OF SUBSTANCE IN RIGHT MEMBRANA TYMPANI.

Inferior end of malleus exposed and free; in the remnant of the membrane is a small hole (*a*); attic filled with connective tissue masses. (From a specimen in the author's collection.)

The changes on the inner tympanic wall can be recognized by inspection only if the perforation is large enough (3–4 mm.) to allow sufficient illumination of the tympanic cavity. Small perforations are visible as black holes after removal of the secretion. Where the orifice is large, the exposed mucous membrane presents different shades of yellowish-scarlet or bluish-red, smooth or uneven, lustrous in parts, and not infrequently covered with firmly adherent layers of exudate and epidermis. The tumefaction is either so slight that the anatomical details of the inner tympanic wall are easily recognized, or so considerable that all the depressions in this wall are erased, giving it the appear-

ance of an even red surface.   When the growth of mucous membrane in this part of the tympanic cavity is very excessive, it may even extend through the perforation above the surface of the membrana tympani.   Sometimes numerous small and large granulations and polypi are formed (Figs. 181 and 182), which extend over the whole field of view, or are arranged in groups; in some very rare cases fibrous growths as hard as cartilage or hyperostotic thickenings are found, which remain as yellow protuberances on the inner tympanic wall after the suppuration has ceased.   Where the defect is very extensive, and even where suppuration is still in progress, it is possible to see the dark orifice of the Eustachian tube in the anterior part of the tympanic cavity; while in its posterior part above the handle of the malleus,
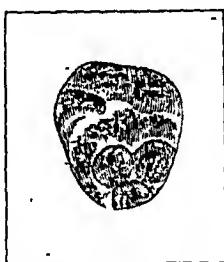
FIG. 181.—THE INFERIOR HALF OF THE LEFT MEMBRANA TYMPANI IS DESTROYED; ON THE DARK RED INNER WALL OF THE TYMPANIC CAVITY ARE SEVERAL GLOBULAR GRANULATIONS. FROM A MAN, 24 YEARS OF AGE, WHO HAD SUFFERED FROM A DISCHARGE FROM THE LEFT EAR SINCE HE WAS 5 YEARS OLD.

Hearing   distance: Acoumeter = 0. Speech = ½ m. In the upper remnant of the membrane the thickened stump of the handle of the malleus is recognizable.
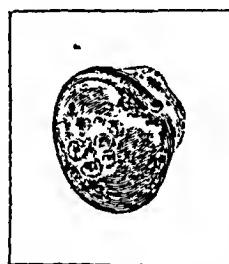
FIG. 182.—EXTENSIVE DESTRUCTION OF THE RIGHT MEMBRANA TYMPANI, OF WHICH A THICKENED REMNANT IS PRESERVED ONLY AT THE SUPERIOR PERIPHERY. GROUPS OF SMALL GRANULATIONS ON THE PROMONTORY. FROM A GIRL, 19 YEARS OLD, WHO HAD SUFFERED SINCE CHILDHOOD FROM A DISCHARGE FROM THE EAR.

Destruction of the growth by touching it with liquor ferri muriatis. The otorrhœa has ceased. Hearing distance: Speech = 2 m.

the incudo-stapedial articulation and the recess of the round window may also be seen.

The contour and form of the remnant of the membrane and the details of the inner tympanic wall become more distinct after the cessation of the suppuration. The remnant of the membrane appears gray, cloudy, and thickened, giving it the appearance of parchment, and is not infrequently calcified to a more or less extent. The chalk deposits present the appearance of sharply defined, chalky-white, or yellow spots, situated between the handle of the malleus and the periphery (Figs. 183, 184, 185), and occasionally attain such a size that nearly the entire remnant of the membrane up to the peripheral portion of the annulus tendinosus is transformed into a rigid, calcareous

mass, penetrating all the layers (Fig. 184). It is a rare occurrence to find a portion of the calcified part projecting freely into the perforation.

In cases of small defects, the handle of the malleus is often embedded in the thickened membrane, so that it can no longer

FIG. 183.—DOUBLE PERFORATION OF THE LEFT MEMBRANA TYMPANI; THE GAPS ARE SEPARATED BY A NARROW BRIDGE; IN FRONT OF THE HANDLE OF THE MALLEUS IS AN OBLONG CALCAREOUS DEPOSIT.

(From a specimen in the author's collection.)
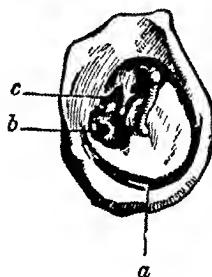
FIG. 184.—EXTENSIVE CALCIFICATION OF THE RIGHT MEMBRANA TYMPANI, INVOLVING ALL THE LAYERS.

a, Peripheral portion not calcified; *b*, Perforation behind the handle of the malleus. (From a specimen in the author's collection.)

be recognized, and only the short process is visible as a knob-like projection at the anterior superior portion of the membrane. Sometimes the hammer is differentiated from the thickened remnant of the membrane by its yellow or red colour. When
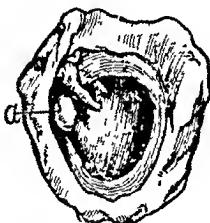
FIG. 185.—EXTENSIVE DESTRUCTION OF THE MEMBRANA TYMPANI; THE INFERIOR EXTREMITY OF THE HANDLE OF THE MALLEUS IS LAID BARE.

a, In front of the handle of the malleus is a calcareous deposit, which partially projects freely into the gap. (Left ear.) (From a specimen in the author's collection.)

FIG. 186.—SMALL PERFORATION BE-HIND THE UMBO. SEMILUNAR CAL-CAREOUS DEPOSIT IN THE ANTERIOR INFERIOR HALF OF THE MEMBRANA TYMPANI.

In a girl, 15 years of age, in whom otorrhœa is said to have appeared about four months ago, and to have ceased since a fortnight. Hearing distance: Watch = 40 cm. Speech = 4 m. (Left ear.)

the perforations have attained a considerable size and the handle of the malleus is partly exposed, it seldom retains its normal position (Fig. 180), but seems more or less inclined inwards and backwards and foreshortened (Fig. 189), and its

inferior extremity is often adherent to the inner tympanic wall.
This place of union is usually above the apex of the promontory,
and is indicated by a circumscribed thickening of the adjoining

FIG. 187.—CENTRAL PERFORATION; IN
FRONT OF AND BEHIND THE HANDLE
OF THE MALLEUS ARE CIRCUM-
SCRIBED CALCAREOUS DEPOSITS IN
THE MEMBRANA TYMPANI.

In a girl, 17 years of age, in whom the
suppuration of the middle ear com-
menced eight years ago and ceased
since two years. Hearing distance:
Speech = 1½ m. (Right ear.)
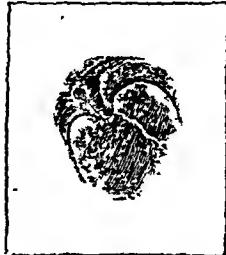
FIG. 188.—LARGE PERFORATION OF
THE MEMBRANA TYMPANI; THE
HANDLE OF THE MALLEUS IS
FORESHORTENED; ITS INFERIOR
EXTREMITY IS IN CONTACT WITH
THE PROMONTORY.

From a young man, 19 years of age, who
was affected with purulent inflamma-
tion of the middle ear during scarlet
fever ten years ago. Hearing distance:
Acoumeter = 1 m. Speech = 1½ m.

mucous membrane. Where a portion of the manubrium is
destroyed by caries, it appears uneven, pointed, or worn away
to a stump, which ends below the short process.

FIG. 189.—EXTENSIVE PERFORATION
OF THE RIGHT MEMBRANA TYM-
PANI. .

The inferior extremity of the handle
of the malleus is adherent to the
inner wall of the tympanic cavity.
The round capitulum of the stapes,
the niche of the fenestra rotunda, and
the ridgy protuberances of the lower
wall of the tympanic cavity are visible.
From a young man, 17 years of age,
in whom the suppuration commenced
during scarlatina, and lasted until
three years ago. Hearing distance:
Watch = 2 cm. Speech = ¼ m.

FIG. 190.—PERFORATION OF THE POS-
TERIOR HALF OF THE RIGHT MEM-
BRANA TYMPANI.

Above the strongly projecting pro-
montory, the long process of the incus
and the posterior crus of the stapes
are visible. From a young man, 16
years of age, in whom the purulent
inflammation commenced two years
ago after a cold bath. Hearing dis-
tance: Acoumeter = 1 m. Speech =
nearly normal.

After suppuration has ceased. the inner tympanic wall assumes
a rose, yellowish-red, or pale yellow colour, and is either moist

or may have its normal appearance. When the tissue has undergone cicatricial thickening, the inner wall is of a tendon-gray colour, uneven and shining; in calcification of the mucous membrane it is intensely white. Vascular ramifications are not infrequently plainly visible on the promontory, and most often, the veins accompanying Jacobson's nerve. If the anterior portion of the membrane has been destroyed, the anterior tympanic space reaching to the tympanic orifice of the Eustachian tube will be visible as a dark depression. If the defect extends nearly to the inferior periphery of the membrane, it is often possible to see a part of the inclined inferior tympanic wall, with its ridgy elevations and dark concavities (these may be mistaken for trabeculæ of granulations). Where the posterior half of the membrane is defective (Figs. 190, 191), the promontory is

FIG. 191.—EXTENSIVE PERFORATION IN THE POSTERIOR AND INFERIOR PORTION OF THE RIGHT MEMBRANA TYMPANI.

In the posterior superior quadrant of the field of view the capitulum of the stapes with the tendon of the stapedius, below it the pale-yellow promontory, and behind it the niche of the fenestra rotunda, are visible. From a man 50 years of age.
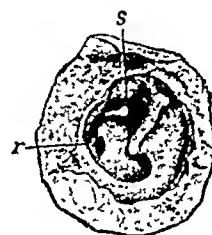
FIG. 192.—PERFORATION OF THE POSTERIOR HALF OF THE RIGHT MEMBRANA TYMPANI.

r, Fenestra rotunda; s, The capitulum of the stapes, with the tendon of the stapedius laid bare by the destruction of the long crus of the incus. (From a specimen in the author's collection.)

seen projecting in the form of a hillock, and above this, the exposed incudo-stapedial articulation (Fig. 190). In those cases in which the inferior part of the long process of the incus is worn away, the two crura and head of the stapes (Figs. 191, 192), with the tendon of the stapedius muscle running backwards, are distinctly visible. It is seldom possible to get a clear view of the chorda tympani (Fig. 193) and the dark recess of the round window at the posterior border of the promontory.

Diagnosis of Perforation of the Membrana Tympani.—In addition to the condition of the membrane found by inspection, the auscultation sound heard with the auscultation tube when using the Valsalva method or during an inflation of air is, in the majority of cases, a positive sign for the diagnosis of a perforation (*vide* p. 106). Where secretion is present, the air passing through the opening in the membrane will be heard as a moist

râle, but in cases in which there is a dry perforation it usually assumes a high and hissing character. A perforation of the membrane may be diagnosed by the simple experiment of filling the external meatus with warm water and then forcing air into the middle ear by an inflation, whereby air-bubbles may be seen on the surface of the fluid. Where no perforation sound is heard during the condensation of the air in the middle ear, it may be concluded that there is a perforation if we follow the suggestion of the author by condensing the air in the external meatus and placing one end of the auscultation tube in the patient's nose, while the other is inserted into the ear of the physician; when the air escapes through the Eustachian tube of the patient, it will be distinctly heard by the examiner (*vide* p. 137).

Fig. 193. — Exposed Chorda Tympani in a Boy aged 9 Years.

Otorrhœa commenced four years ago, and ceased since six months. By touching the nerve a piercing pain and sour taste were experienced on the tip of the tongue.

Kugel's experiment for demonstrating the presence of a perforation of the membrane before a number of persons, consists in hermetically introducing into the external meatus a rubber tube having an olive-shaped nozzle, and allowing its free extremity to hang in a glass of water. In performing Valsalva's or Politzer's method, air-bubbles will be seen to rise in the water from the free end of the tube. Sometimes it is possible, according to Pins, to obtain notes from a small whistle placed hermetically into the external meatus by the escape of the air through the perforation.

The diagnosis of perforation is rendered more difficult if the opening in the membrane is occluded by exudate or granulations, or if the margins of the perforation rest against the inner tympanic wall and the sharp boundary between the membrane and the mucous membrane of the tympanic cavity is effaced. In such cases, the seat of the perforation is ascertained only in the further course of the disease, when the swelling of the membrane decreases and the accumulated masses of exudate and epidermis are cast off. When the perforation is large, and the reddened (or tendon-gray), shining inner tympanic wall shows a great similarity to the pathologically altered membrane, it is often difficult to detect the perforation by inspection, so that the diagnosis of such a large defect can be made only by the relative position of the remaining parts of the membrane or stump of the hammer to the deeper parts of the tympanic cavity. In doubtful cases, the seat of the perforation can often be discovered only by means of Siegle's speculum. If the air in the external meatus is rarefied, a drop of pus will often come into view, indicating the seat of the perforation. In like manner, by condensing the air in

the external meatus, the perforation may become visible for a moment as the air is forced through. The pneumatic speculum may also be used with advantage as a means of diagnosis if one is in doubt whether the uneven, granulating surface taking in the entire field of vision is the membrane or the inner tympanic wall; in the former case, the reddened surface will show a decided mobility by alternate rarefaction and condensation of the air in the external meatus, while in the latter case all mobility will be absent.

Siegle's speculum is furthermore of diagnostic value for the purpose of localizing circumscribed suppurative processes in the middle ear, which cannot be seen on inspection. Such localized suppurations may continue in the attic and mastoid antrum, while the secretion in the visible parts of the tympanic cavity has ceased entirely. If, in such cases, the air in the external meatus is aspirated by means of the pneumatic speculum, pus will be seen to appear in the perforation at the posterior superior quadrant of the membrane, which becomes more profuse as aspiration is continued. If during this aspiration a rather large quantity of pus appears in the posterior superior quadrant, it may be concluded with great probability that we are dealing with an attic and antral suppuration; while a small quantity of secretion before or behind the handle of the malleus indicates a suppurative process in the attic alone. In a number of cases the author was also able to locate circumscribed suppurations in the region of the Eustachian tube by means of the Siegle speculum.

Chronic Suppurations of the Middle Ear with Perforation of the Pars Flaccida (Shrapnell's Membrane).

Those chronic midde-ear suppurations running their course with perforation of the pars flaccida deserve special consideration from a diagnostic, as well as from a therapeutic, point of view.

In the majority of cases, perforation of Shrapnell's membrane associated with an intact membrana tympani is produced by an inflammatory condition of the entire middle ear. In these cases the attic suppuration often remains as the residuum of a suppurative process in the tympanic cavity, which has run its course. Sometimes, however, it is occasioned by a suppurative inflammation localized in the external attic, which is seldom recognized clinically in its primary stage.

That it may arise slowly and without reaction is shown by the fact that one often sees suppurations with perforation of the pars flaccida which are not preceded by any symptoms of a reactive inflammation.

In such cases, therefore, the opinion expressed by some observers that it sometimes arises through infection from the external auditory canal must not be disregarded. In a great

number of cases the author has been able to observe its development during the course of a chronic middle-ear catarrh; this was due to the fact that a deep groove was formed above the processus brevis in consequence of a marked retraction of the atrophic pars flaccida and its apposition to the neck of the hammer, whereupon the growth of the epidermis of the external meatus into this depression caused a continuous pressure upon the pars flaccida, thereby creating a perforation.

According to Hartmann, it is often possible to find adhesions between the membrana tympani and the inner tympanic wall in middle-ear suppurations complicated with perforation of the pars flaccida. Perforation of Shrapnell's membrane is occasionally the symptom of a suppuration of the mastoid antrum, particularly in those cases in which the greater part of the membrana tympani is adherent to the inner tympanic wall.

The author's anatomical investigations show that defects of the membrana tympani occur more often with a simultaneous perforation of the pars flaccida than has been generally supposed. It is often overlooked, because it is hidden by the accumulation of macerated epidermis and the swelling of the surrounding parts. We are frequently able to discover the perforation only after the macerated epidermis and dried secretion has been thoroughly removed.

Secretion or air seldom appears in the perforated pars flaccida during Valsalva's method or an inflation of air, because the places of communication between the external attic and the tympanic cavity become occluded by the collection of secretion, swelling, granulations, or adhesions. Sometimes we are able to diagnose a perforation of the pars flaccida by the appearance of a drop of pus above the short process of the hammer during rarefaction of the air in the external meatus by means of the pneumatic speculum.

The appearance of the membrane in middle-ear suppurations running their course with perforation of Shrapnell's membrane varies according to the amount of loss of substance, the extent of the swelling of the neighbouring parts, and the condition of Prussak's space. When the discharge is slight, a round or oval, dark red opening, or one filled with a grayish-yellow secretion, is seen after the removal of the secretion (which is usually of a curdy nature) or macerated epidermis; this orifice is almost always located above the short process of the malleus, seldom behind it. The perforation is found much more frequently in the central than in the anterior or posterior parts of the pars flaccida. The vessels in the region of the short process and handle of the malleus are injected; the membrane itself is sometimes only slightly altered in suppurations confined to the attic, and usually appears gray, cloudy, lustreless, and at times retracted.

Prussak's space is filled either with a thin fluid or with curdy secretion, after the removal of which the cavity is seen to be lined with reddened mucous membrane or macerated, firmly adherent epidermis, or filled with granulations.

When, in cases of localized suppuration of Prussak's space, or of the external attic, the process heals, one finds the sharply-defined opening presenting a dark gray colour and its margins overgrown with epidermis; in addition to this, the groove-like depression which is bounded by the neck of the hammer is covered with a shining cicatrix.

FIG. 194.—PERFORATION IN THE POSTERIOR SUPERIOR QUADRANT OF THE MEMBRANA TYMPANI AND ALSO OF THE MEMBRANA SHRAPNELLI.

In a man, aged 21 years, who has had otorrhœa for five years. Complete deafness of the left ear.

In diffuse middle-ear suppurations complicated with perforation of the pars flaccida, an oval aperture is usually seen in the posterior part of the membrana tympani (Fig. 194), with or without adhesion of its anterior part to the inner tympanic wall. In other cases the entire inferior part of the membrane is defective, and is only separated from the perforated pars flaccida by a broad remnant, which encloses the handle of the malleus. A condition of practical importance, and worthy of notice in perforation of Shrapnell's membrane, is a marked bulging of the posterior segment of the membrana tympani, which is due either to an encapsulated purulent or cholesteatomatous mass, or to the growth of granulations; in order to remove such accumulated masses it is necessary to incise this portion of the membrane.

Attic suppurations associated with perforation of the pars flaccida are characterized by their obstinate course. The reason for this may be explained by the fact that the secretion lying in the spaces formed by the folds of mucous membrane in the external attic becomes encapsulated, and cannot be easily reached by irrigation.

The chronic suppurations of the external attic, as well as those combined with perforation of the pars tensa, lead to the formation of granulations and polypi, which force their way through the perforation into the external meatus. The presence of small polypi varying in size from a millet- to a hemp-seed, and situated above the short process of the malleus, can be recognized without any difficulty.* On the other hand, we cannot tell whether the large polypi, which cover the greater part of the membrane as red, uneven masses, or completely fill the bony meatus, arise

* Compare Politzer, *Atlas*, Plate XIV.

from the external attic until the growths have been removed by operative procedures. Small granulations arising from the neck of the malleus seldom recur after their removal, while those growths springing from the upper portion of the attic or from the malleo-incudal body show a great tendency to reappear. The formation of cholesteatomata in the external attic is still more common, and is almost always brought about by the inward growth of the epidermis of the external meatus into this portion of the middle ear (*vide* section on Cholesteatoma). Such a formation of cholesteatomatous masses in the attic may give rise to extensive changes in the temporal bone.

Chronic suppurations of the attic may run their course for years without any symptoms. Sometimes, however, they are accompanied by intercurrent pains in the ear, hemicranial headaches, a feeling of pressure and heaviness in the head, and violent attacks of dizziness. The last-mentioned head symptoms usually occur with the formation of granulations and cholesteatoma in the attic, with caries of the external attic wall, and with the development of suppurations in the antrum and cholesteatoma in the mastoid cells.

When the suppuration of the attic continues a long time, it not infrequently leads to caries and necrosis of the malleus and incus, and to absorption of the bone above the Rivinian segment, whereby defects are produced in the superior wall of the meatus above the short process of the hammer, which in some cases attain such a size that a great part of the attic is exposed to view.*

The clinical picture in such cases varies according to the size of the bony defect, whether the structures of the tympanic cavity have retained their anatomical forms, and whether the suppuration is still in progress or has subsided. In cases in which the discharge still continues, the defect in the bone is filled with a curdy, septic secretion, with cholesteatomatous masses or with granulations which grow into the lumen of the external meatus above the level of the gap (Fig. 195). It is only after the removal of these masses that it is possible to inspect the cavity produced by absorption of the bone and to get a good view of that part of the attic corresponding to this defect.

The picture after an exhausted suppuration is more easily recognized. When the defect is small, we can distinctly see in the background either a tendon-gray, lustrous cicatrix (Fig. 196), or the yellow neck and a portion of the head of the hammer. If the bony defect is large and very readily recognized, the superior, free margin of the membrane will be found to be sharply defined (Figs. 197 and 198), and the malleo-incudal articulation sometimes so completely exposed that its various anatomical details can

* According to Walb (*A. f. O.*, 26), as sequel to a primary suppurative ostitis of the margo tympanicus.

be clearly seen * (Fig. 197). In cases in which the incus was destroyed the author has repeatedly seen the head of the malleus lying free (Fig. 198); if this was also destroyed, and there was a simultaneous defect in the posterior segment of the membrane, one could readily see the recess of the oval window and the Fallopian canal lying above it; if the gap was still larger and the defect extended further back, the author could even see the prominence of the horizontal semicircular canal and a portion of the antrum. Under these conditions the membrane appears

FIG. 195.—DESTRUCTION OF SHRAP-NELL'S MEMBRANE IN THE LEFT EAR.

At the incisura Rivini a jagged gap in the bone is seen, through which the mucous membrane of the tympanic cavity is growing. From a girl, 16 years old. in whom suppuration of the middle ear had existed for four years. Lately she had had continuous headaches and twitchings of the facial muscles. In spite of repeated removal of the protruding new formation, it again and again grew into the external meatus. But after several injections of warm water into the tympanic cavity by means of the catheter, recovery took place.

FIG. 196.—GAP THE SIZE OF A SMALL LENTIL ABOVE THE SHORT PROCESS, THE BASE OF WHICH IS LINED BY A SMOOTH, DRY AND GRAY CICATRIX.

From a girl, 20 years old, who had suffered from an ear affection since childhood. The suppuration is localized in the space above the short process. The suppurating cavity was cleansed by means of a small tympanic tube inserted from the meatus, and then a few drops of a 10 per cent. solution of nitrate of silver were injected through the same tube, by which the secretion was arrested on the following day. Several subsequent slight relapses were quickly cut short by the same treatment. Hearing distance: Acoumeter$=11$ cm. Speech$=1\frac{1}{2}$ m.

gray, cloudy, thickened, calcified, either partially or completely adherent to the inner tympanic wall, and even extensively destroyed if the suppuration of the middle ear is diffuse.

With these suppurative processes confined to the external attic, even if combined with extensive defects of the outer attic wall, the disturbance of hearing is usually found to be very slight. This is a very important point, as the author was the first to show, in aiding us to make a differential diagnosis between the primary forms of attic suppuration and those complicated with diffuse suppurations of the middle ear.

Even in cases in which the attic suppuration has existed for some time, and the process is confined to this portion of the middle

* Compare A. Politzer, *Beleuchtungsbilder des Trommelfells*, 1895, p. 122, and *Atlas*, Plate XIV., 13–19.

ear, the hearing is usually well preserved, as there is no marked impairment in the sound-conducting apparatus. On the other hand, however, when there is a coexisting middle-ear involvement, the hearing power may suffer to a more or less degree.

The treatment of these conditions will be given in a later paragraph (p. 435), and the sequelæ requiring special treatment will also be discussed later on.

Pathological Changes in the External Auditory Canal in Chronic Middle-Ear Suppuration.—The lining of the external auditory canal undergoes many changes through long contact with the secretion from the middle ear, and through extension of the inflammatory process from the tympanic cavity.
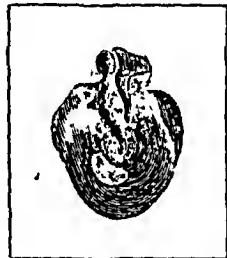
FIG. 197.—AN EXHAUSTED SUPPURATION OF THE MIDDLE EAR. LARGE DEFECT IN THE BONE ABOVE THE RIVINIAN SEGMENT, WHICH IS CLOSED BY A VERY THIN DEPRESSED MEMBRANE.

Head of the malleus, body of the incus, and anterior ligament of the malleus distinctly visible. From a woman, 26 years of age. Hearing distance: Acoumeter = 50 cm. Whispered speech = 5 m.

FIG. 198.—A LARGE DEFECT IN THE BONE ABOVE THE RIVINIAN SEGMENT, THROUGH WHICH THE HEAD OF THE HAMMER IS VISIBLE.

In a woman, 30 years of age, who had suffered from otorrhœa since 10 years of age. Whispered speech = 2½ m.

The following are the most frequent changes: Follicular or diffuse inflammation, hypertrophy of the cutis, stricture of the canal, and the formation of granulations and polypi. Rarer sequelæ are the following: Inflammation and thickening of the periosteum of the bony portion of the meatus terminating in hyperostosis and exostosis, the formation of ulcers and erosions (in scrofulous persons), caries and necrosis of the osseous walls, and gangrene of the cartilaginous meatus.

In children and in persons with a delicate, irritable skin, it is found that the action of the secretion on the auricle and external region of the ear often produces a moist eczema; sometimes this process leads to deep-seated ecthymatous pustules, and occasionally to a chronic diffuse dermatitis with enlargement of the thickened and rigid auricle. Swelling of the glands at the back and side of the neck, more rarely of the retro-auricular lymph-glands, is of frequent occurrence, and is seen especially in

children. This glandular infiltration can, in the majority of cases, be traced to some focus of suppuration in the neighbourhood, and we are justified in assuming it to be due to a lymphatic diathesis only if other characteristic signs of a lymphatic nature are at hand. The purulent middle-ear process also frequently changes the character of the secretion of the ceruminous and sebaceous glands, so that one finds a curdy, scaly secretion, or an excessive growth of epidermis in the meatus, instead of ·the normal cerumen, after the suppuration has run its course; this abnormal accumulation of secretion in the external meatus may extend through the perforation into the tympanic cavity, and may form the basis of cholesteatomatous masses, which will be described later.

Symptoms of Chronic Middle-Ear Suppuration.—Chronic suppuration of the middle ear often runs its course without any striking subjective phenomena. Tenderness, or frequent attacks of pain, usually develop when there is an intercurrent acute inflammation of the middle ear and external auditory canal, and when the discharge of pus is prevented through temporary closure of the perforation, through stricture of the meatus, or through polypoid growths. This form of inflammation is furthermore accompanied by severe pain, when the pus becomes sacculated, when the cheesy masses in the cavum tympani and the mastoid process undergo decomposition, when the mucous membrane becomes ulcerated, and finally when there is caries of the temporal bone. The pain is seldom due to neuralgia.

The usual symptoms of chronic inflammation are: A feeling of pressure and heaviness in the head, or obstinate headache, which, in unilateral affections, is generally localized in the corresponding side of the head or occiput. These head symptoms are often caused by a hyperæmia which is transmitted to the scalp. The above-mentioned symptoms are most often observed in cases in which the outflow of pus is hindered, or in which inspissated masses accumulate in the middle ear.

Giddiness, or marked attacks of dizziness with vomiting, unsteadiness of gait, and increased tinnitus, are sometimes the symptoms of slight temporary changes in the labyrinth. These symptoms are observed most frequently in association with the formation of cholesteatoma in the attic and mastoid antrum, with abundant granulations in the middle ear, with extension of the inflammation to the labyrinth, and finally with cerebral complications.

The annoying head symptoms generally disappear with the cessation of the suppuration. Surprisingly rapid relief is often obtained after the removal of the inspissated secretion, cholesteatomatous masses and polypi from the middle ear. Occasionally, however, the reverse is found to be the case, inasmuch as a constant feeling of pressure and pain in the head arises after the

cessation of the suppuration, which does not disappear until the discharge in the middle ear again returns.

Subjective noises are much more rarely met with in this form of disease than in chronic, non-perforative middle-ear catarrhs. The reason for this may be explained by the fact that when there is a perforation an immediate equalization of the air-pressure between the external atmosphere and the middle ear takes place, and the labyrinth is less often involved in the non-complicated forms of chronic middle-ear suppurations. The noises are usually intermittent. Those of a continuous nature are generally observed in anæmic, cachectic, hysterical, and nervous individuals, in a consecutive exudation into the labyrinth, in syphilitic affections of the ear, and in adhesive processes of very long standing. They are considered of evil prognostic import in regard to the restoration of the hearing.

Alterations in the taste, such as a diminution or total loss, which are brought about by a pathological condition of the chorda tympani, and of the glosso-pharyngeal which takes part in the formation of the tympanic plexus, are occasionally observed in chronic suppurations of the middle ear. When the chorda tympani is affected, the anterior third of the tongue is affected; while in lesions of the tympanic plexus, the soft palate, the posterior pharyngeal wall, and mucous membrane of the cheeks are the parts involved. Although these alterations in the taste may seem very marked while testing, still the patients seldom complain of them when eating or drinking. Sometimes a change in the tactile sense is also observed in the tongue. An alteration in the sense of smell, as a loss of perception for different odours, or anosmia, is some-times seen, and may be attributed to a simultaneous naso-pharyngeal affection or to a paresis of the olfactory nerve. Unpleasant subjective odours, without any apparent cause, are exceedingly rare.

Disturbances of Hearing.—The power of hearing shows great variation during the course of a middle-ear suppuration. Such a fluctuation may be attributed partly to the varying degree of swelling of the mucous membrane of the middle ear and per-meability of the Eustachian tube, and partly to the quantity of secretion in the cavum tympani. Changes in the weather and temperature exercise a decided influence on the power of hearing. Warm and dry weather have a favourable influence, while cold and moist weather are decidedly injurious. A tem-porary or permanent diminution in the hearing is observed in recurrent inflammations of the middle ear, in intercurrent naso-pharyngeal catarrhs, in debilitating general affections, after parturition, in marasmus, and in general syphilis. Fluctuations in the hearing are also observed in extensive hypertrophy of the mucous membrane of the middle ear completely enclosing the ossicles, in firm adhesions or ankylosis of these bones, and in advanced labyrinthine affections.

After the suppuration has run its course the degree of disturb-ance of hearing depends mainly on the pathological changes which remain in the middle ear. If the intense swelling of the

mucous membrane again subsides, a marked improvement in the hearing will always follow, and the hearing function may return to almost its normal state even if there are permanent changes in the membrana tympani. If, on the other hand, the ossicles have become immovable through the formation of succulent or cicatricial tissue, and especially if the recesses of the round and oval windows have become filled with thickened mucous membrane, thereby fixing the stapes in the pelvis ovalis, no improvement in the hearing, or only one of a slight degree, will be noticed after cessation of the discharge. It even happens that a striking change for the worse is noticed immediately after the cessation of the suppuration, which again improves with the reappearance of the discharge. This condition may be explained by the fact that the connective tissue, which has become firm, again relaxes by the return of the suppuration, and the ossicles thereby attain a greater mobility. Slight disturbances of hearing, which follow exhausted middle-ear suppurations, often remain stationary for many years. Progressive increase in the deafness and a striking change for the worse are observed in advanced age and in cachectic individuals.

The perception through the cranial bones is generally normal. It is diminished, or entirely absent, only in advanced age, in adhesive middle-ear processes which date from childhood, and in a simultaneous affection of the labyrinth. The results of Weber's test are, as a rule, analogous to those obtained in middle-ear catarrhs; the same applies to Rhinne's and Schwabach's tests (p. 282).

Course and Terminations.—The course of this chronic inflammation depends on the cause, on the local changes in the middle ear and labyrinth, on the condition of the naso-pharynx, and on the general condition of the patient. Since the terminations and sequelæ of chronic middle-ear suppurations present such great variations, we must confine ourselves to a general description.

The suppuration is either of long standing over a period of years or only of a short duration of several months. The former is observed especially in the lymphatic, tubercular, scarlatinal, diphtheritic, and syphilitic forms; furthermore, with diffuse granulations, with cholesteatomatous masses, with polypi, and with caries. It frequently happens that the discharge ceases spontaneously, only to return with or without reactive symptoms after a short pause, or after an interval of many years. The relapses are most frequently caused by a cold in the head, by the entrance of water into the meatus while washing or bathing, by intercurrent naso-pharyngeal infections, or by organic or general febrile diseases. Relapses of middle-ear suppuration are especially frequent in those cases in which the perforation in the membrane remains patent, because the mucous membrane of the

middle ear is exposed to the immediate action of external harmful influences. In these cases, the air also enters the tympanic cavity more easily when blowing the nose, whereby the bacteria in the naso-pharynx are readily forced into the middle ear. The time of the year also exercises an influence on the suppurative process; this is especially noticeable in children, in whom the discharge often ceases in the spring and reappears in the autumn, being generally associated with a naso-pharyngeal catarrh.

It must be mentioned, however, that sometimes, especially in the desquamative processes of the middle ear, the suppuration apparently ceases in the parts of the tympanic cavity which can be easily inspected, while it continues in the antrum or mastoid process.

The suppurative process ceases, as a rule, uniformly over the entire mucous membrane of the middle ear and membrana tympani. Nevertheless, cases are often seen in which the remnant of the membrane is dry and lustrous, while the inner tympanic wall is still covered with pus, or *vice versa*. In like manner, in cases of extensive destruction of the membrana tympani, one finds circumscribed parts of the tympanic mucous membrane covered with dry, lustrous cicatricial tissue and epidermis, while other parts are still covered with pus, after the removal of which a red, tumefied or granulating area is brought to view.*

The appearance of the parts during the suppuration is subject to many variations. It is frequently found that the condition remains unchanged for years, but more often, however, especially after acute intercurrent relapses, one finds within a short time quite a different picture from that seen at the previous examination. Sometimes, even after an interval of several weeks, there will be a marked enlargement, seldom a diminution in the perforation, or one will see a cicatricial adhesion between the membrane and the deeper parts of the tympanic cavity. In like manner, the condition may be entirely altered by the rapid growth of granulations and polypi in the middle ear. Occasionally the perforation changes its location, inasmuch as it wanders from the centre towards the periphery.

The terminations of chronic suppurations of the middle ear are: (1) Cure, after cessation of the suppuration, with complete restoration of the hearing; (2) disturbances of hearing of different degrees up to complete deafness, especially if connective-tissue adhesions have formed in the tympanic cavity and in the recesses of the windows, by which the ossicles have become immovable and the membrane of the round window abnormally thickened; these cases are usually associated with more or less permanent destruction of the drum; (3) desquamation and the formation of cholesteatoma in the middle ear; (4) ulcerative and cario-necrotic processes in the temporal bone and their sequelæ;

* Compare Politzer, *Atlas*, Plate VII., 12.

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(5) disturbances in co-ordination, vertigo, and nystagmus due to secondary involvement of the labyrinth. This may be in the form of a serous or purulent labyrinthitis (fistular symptom), with secondary changes in the auditory nerve.

We will next discuss the formation of cicatrices on the membrane, the adhesive processes after exhausted middle-ear suppurations, the persistence of perforations of the membrana tympani, and cholesteatoma of the ear.

I. Closure of the Perforation by Cicatricial Tissue.

Closure of the perforation of the membrane by a cicatrix is more rarely met with in chronic than in acute suppurations of the middle ear. The reason for this lies in the fact that in chronic cases the epidermis of the external surface of the membrane often grows over the margins of the perforation before cicatricial tissue has had time to develop. As a rule, however, a small loss of substance is more often closed by cicatrization than an extensive one.

The cicatrix develops either uniformly from the margins of the perforation, or from one part of the orifice (Fig. 199), or a ligamentous bridge is formed, which runs directly across the opening, the margins of which become united with those of the perforation, making a cicatrix which completely replaces the loss of substance.

The experiments of Rumler (*A. f. O.*, vol. xxx.) on animals, by which he showed that cicatrization of the membrane took place mainly from its external epithelial layer, do not apply to all pathological cases, as the author was able to demonstrate that the cicatrix also developed from the mucosa of the membrane in many of the specimens in his collection (cp. Politzer, *Atlas*, p. 118).

The cicatrices usually appear as depressed, sharply-defined, dark spots of varying size, at the bases of which irregular light reflexes are visible. Their form is either round or elliptical (Fig. 201) and often kidney-shaped (Fig. 200). As a rule, only one cicatricial depression is found; still, there are not infrequently cases in which there are two (Fig. 201) or even more of these scars or cicatricial-like depressions, many of which doubtless arise from partial atrophy of the remnant of the membrane. The tissue of the membrane in the neighbourhood of the scar is more or less cloudy, thickened in parts, and calcified to a varying extent (Figs. 199 and 202).

Cicatrices are classified into three varieties—the free, the applied, and the adherent. The free are, as a rule, of small size, and are seldom so depressed as to come into contact with the inner tympanic wall. Large cicatrices, especially those situated behind the handle of the malleus, almost always lie so close to the inner tympanic wall that the contour of the promontory, the recess of the round window, the incudo-stapedial articulation or the head of the stapes, can be seen almost as clearly as if there were an extensive destruction of the membrane (Fig. 204).

Cicatrices of the membrane remain either unaltered after closure of the perforation, or, later, increase in size. The author has repeatedly observed a wandering of the scar in the

FIG. 199.—PERFORATION IN THE ANTERIOR INFERIOR QUADRANT OF THE LEFT MEMBRANA TYMPANI.

From the posterior margin of the defect there extends cicatricial tissue, which does not quite close the gap. Behind the handle of the malleus is an irregular calcareous deposit. From a man, 64 years of age. Duration one year. After treatment for a fortnight the suppuration ceased. Hearing distance: Speech = 5 m.
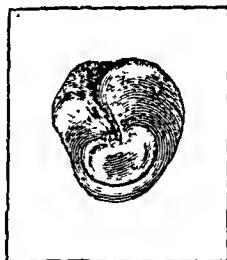
FIG. 200.—KIDNEY SHAPED CICATRIX BELOW THE HANDLE OF THE MALLEUS.

From a woman, 48 years of age, in whom purulent inflammation of the middle ear commenced two years ago, but ceased after a few weeks. Great deterioration in the hearing power after closure of perforation. Hearing distance: Watch = in contact with auricle. Speech = 1 m.

membrane, and in a number of cases a destruction of the cicatrix, during an acute exacerbation of the middle-ear suppuration. The diagnosis of free cicatrices is, as a rule, not difficult.

FIG. 201.—LARGE CICATRIX BEHIND THE HANDLE OF THE MALLEUS.

In a man who suffered in childhood from otorrhœa on the right side. While under observation a cicatricial-like atrophy arose in front of the handle of the malleus. Hearing distance: Watch = 0. Speech = ⅓ m.
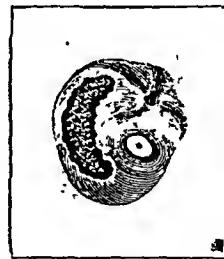
FIG. 202.—CICATRIX, THE SIZE OF A PIN'S HEAD, IN FRONT OF THE HANDLE OF THE MALLEUS; BEHIND IT, A SEMILUNAR CALCIFICATION.

From a man, 50 years of age, who had a discharge from the ear since childhood, but whose hearing became impaired only half a year ago. Hearing distance: Acoumeter = ⅓ m. Speech = 4½ m.

Small, sharply-defined dark scars may, at the first glance, be mistaken for perforations. Such an error may, however, be avoided if we take into consideration the absence of the perfora-

tion sound during an inflation of air into the middle ear, and the subsequent globular bulging of the depressed part above the level of the other portions of the membrane. When the Eustachian tube is permeable, free cicatrices often present a certain amount of mobility due to a change of air-pressure in the tympanic cavity during the act of swallowing or during quiet respiration through the nose (Blake's manometrical cicatrix). Such cicatrices exhibit a striking degree of mobility while testing with the Siegle speculum. Larger thin scars lying against the inner tympanic wall are recognized by the shining folds extending from the former margins of the perforation to the inner tympanic wall, and by the blister-like, irregular bulging after an inflation of air into the middle ear,* causing the structures which were formerly visible on the inner tympanic wall to entirely disappear from

FIG. 203.—LARGE HEART-SHAPED CICATRIX BELOW THE HANDLE OF THE MALLEUS; BEFORE AND BEHIND IT TWO SHARPLY-DEFINED CALCAREOUS SPOTS.

From a girl, 19 years old, who suffered from otorrhœa since childhood until six years ago. Hearing distance: Watch = 25 cm. Speech = 2 m.

FIG. 204.—LARGE CICATRIX BEHIND AND BELOW THE HANDLE OF THE MALLEUS.

From a man 34 years old. Duration since childhood. After propelling air into the middle ear, the cicatrix, lying against the wall of the tympanic cavity, bulges forward in the form of a bubble towards the external meatus. Hearing distance: Acoumeter = 2 cm. Speech = $\frac{1}{2}$ m.

view. The latter procedure is of special diagnostic value in those cases in which the scar assumes the form of a blind sac, and in which the sides are hidden by the remnant of the membrane (Fig. 205). Scars which extend over the posterior half of the membrane are sometimes so strongly bulged out by the air-douche that the handle of the malleus is almost entirely covered by this blister-like protrusion.

The free cicatrices seldom occasion any striking disturbance of hearing, and one is justified in attributing the deafness to the cicatrix only if, after the bulging of the same by an air-douche, an improvement in the hearing is obtained, which again disappears as soon as the cicatrix sinks back into its former position.

* Cp. Politzer, *Plastische Darstellungen der wichtigsten Krankheiten des Trommelfells*, No. 11, and *Atlas*, Plate XII., 22-27.

Cicatrices lying in contact with the promontory are, as a rule, associated with deafness. A marked improvement in the hearing is often obtained if the cicatrix is forced towards the external meatus by an inflation of air. This outward bulging of the scar may, however, bring about a temporary change for the worse in those cases in which there is an interruption in the union between the long process of the incus and the head of the stapes, and in which the cicatrix lying in contact with the stapes acts as the direct means of transmission for the waves of sound.
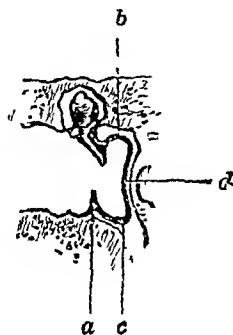
FIG. 205.—DIAGRAMMATIC SECTION IN WHICH THE POSITION OF AN EXTENSIVE CICATRIX OF THE MEMBRANA TYMPANI, IN CONTACT WITH THE INNER WALL OF THE TYMPANIC CAVITY, IS ILLUSTRATED.

a, Ledge-shaped remnant of the membrane; *b*, *c*, The lateral portions of the cicatrix; *d*, Portion of the cicatrix applied to the inner wall of the tympanic cavity.

FIG. 206.—DETACHMENT OF THE HANDLE OF THE MALLEUS FROM THE TYMPANIC MEMBRANE.

a, Membrana tympani; *b*, Inferior extremity of the handle of the malleus, detached from the membrane.

In larger central defects, cicatrization sometimes takes place without involving the inferior end of the malleus, which is inclined inwards. This detachment of the handle of the malleus from the membrane, which has become soft through inflammation, often occurs during the time of suppuration, owing to the action of the tensor tympani muscle. The separation is either complete, or there are (Fig. 206) bridges of connective tissue or bands between the manubrium and the membrana tympani.

Detachment of the manubrium can be diagnosed in the living only if its upper part stands out sharply at some particular place, if the umbo is very flat, and if this portion of the membrane is very movable during examination with the Siegle speculum. It is self-evident that the transmission of sound from the drum to the ossicles is impaired by the detachment of the malleus from the membrane.

II. Adherent Cicatrices ; Adhesions between the Membrana Tympani and the Inner Tympanic Wall ; Connective-Tissue Formation in the Cavum Tympani.

The conditions are different in those cases in which the cicatrix of the membrane is united with the inner tympanic wall. Such an adhesion may be produced either by the immediate contact of

the inflamed surface of the membrane and inner tympanic wall, which have become denuded of their epithelium, or by granulations, which bring about an immediate union between the tympanic walls, the ossicles, and the membrane.

Smaller cicatrices seldom become adherent to the inner tympanic wall. Where this does occur the cicatrices form funnel-shaped depressions, which become narrower as they proceed inwards, and have black or reddish backgrounds; while testing with the Siegle speculum, or during an inflation of air into the middle ear, it is found that these scars remain stationary or exhibit only a slight movement. The author often found them below and behind the handle of the malleus (Figs. 207, 208), but most frequently in the posterior superior quadrant
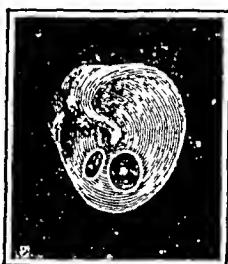
FIG. 207.—ADHERENT CICATRICES, WITH A REDDISH-GRAY BACKGROUND IN THE MEMBRANA TYMPANI BELOW THE HANDLE OF THE MALLEUS.

From a girl, 10 years old, who suffered for a short time from otorrhœa during the course of measles in the second year of her life. Hearing distance for the watch = 2 cm. For loud speech = 1 m.

FIG. 208.—DIAGRAMMATIC SECTION THROUGH THE EXTERNAL MEATUS AND THE TYMPANIC CAVITY, SHOWING THE ADHESION OF A CICATRIX, SITUATED BELOW THE HANDLE OF THE MALLEUS, TO THE INNER WALL OF THE TYMPANIC CAVITY.

r, Membrana tympani; *a*, Cicatrix adherent to the promontory.

of the membrane, in which case the incudo-stapedial articulation or the head of the stapes alone was embedded in the cicatrix.

It is more often found that large cicatrices lying in immediate contact with the inner tympanic wall become partially or wholly united. This union usually takes place during the secretory stage. The suppuration often ceases after the membrana tympani has become adherent to the inner tympanic wall; sometimes, however, the discharge continues in spite of this union, or ceases in certain portions of the tympanic cavity which have been closed off by the adhesions, while it obstinately continues in other parts. During the aural examination it is found that the adherent parts do not change their position after an inflation of air or on testing with the Siegle speculum, while the parts of the membrane which are free show a decided mobility. The

border between the adherent and the non-adherent parts is often demarcated by a white or gray line, at which place the movements of the free parts are sharply limited.

The adhesive processes produced by middle-ear suppurations are so variable that the conditions found in one ear seldom correspond to those found in another. Considering, however, the practical significance of this subject, we will briefly detail in the following paragraphs the most important conditions met with in the adhesive processes.

A condition most often found is the adhesion of a cicatrix, extending over the posterior half of the membrane, to the posterior and inner walls of the tympanic cavity. This is characterized by a sharp, semilunar boundary line between the remnant of the membrane and cicatrix, and by the marked prominence of
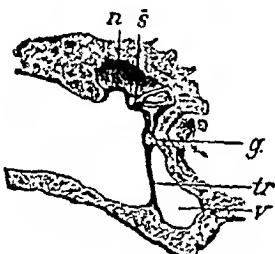
FIG. 209. — HORIZONTAL SECTION THROUGH THE MEATUS AND TYMPANIC CAVITY.

tr, Free anterior portion of the membrana tympani; *n*, Cicatrix adherent to the posterior and inner walls of the tympanic cavity; *s*, Head of the stapes grown into the cicatrix.

FIG. 210.—PERFORATION IN THE ANTERIOR FREE PORTION OF THE MEMBRANA TYMPANI. THE POSTERIOR SUPERIOR PORTION IS ADHERENT TO THE PROMONTORY.

In a woman, aged 28, who had otorrhœa since childhood. Acoumeter $=\frac{1}{2}$ m. Whispered speech $=\frac{1}{7}$ m.

the promontory, showing the recess of the round window, the incudo-stapedial articulation, or the head of the stapes alone when the long process of the incus has been destroyed by caries. Sometimes the anterior free part of the membrane is found perforated, while its posterior half is adherent to the inner tympanic wall (Fig. 210).

Large cicatrices which take in nearly the entire area of the membrane, and which are united with the inner tympanic wall, form blind pouches which separate the inferior and middle tympanic spaces of the tympanic cavity from the Eustachian tube, the mastoid antrum, and the upper tympanic space. Occasionally, in such cases of adherent culs-de-sac, there is still a communication between the tube and the upper tympanic space, which can be proved by auscultation. More frequently, however, the part of the tympanic cavity outside these sacs is so completely filled with connective-tissue masses that the air is prevented from entering the middle ear.

In the examination of extensive adherent cicatrices, the handle of the malleus, which is usually thick and strongly inclined inwards, is seen standing out prominently above the level of the cicatrix. The contour of the inner tympanic wall is more or less clearly defined. The remnant of the membrane either passes into the cicatrix without any visible line of demarcation, or this place of union is designated by a sharp angular bend. The surface of adherent cicatrices appears either dry, lustrous, or covered with secretion.

The diagnosis of these adherent saccular cicatrices, which is made by inspection and by the immobility of the parts during the examination with Siegle's speculum, may be substantiated by gently touching the depressed portions with a blunt probe. If the parts which remain immovable on forcing air into the middle

FIG. 211.—FRONTAL SECTION THROUGH THE MEATUS AND TYMPANIC CAVITY.

r, Sickle-shaped remnant of the membrana tympani; *t*, Cicatrix which extends inwards with a sharp bend from here and lies upon the promontory (*p*).
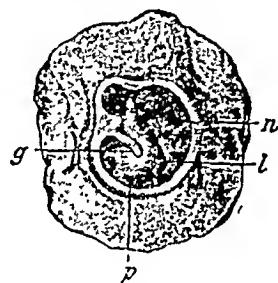
FIG. 212.—LARGE APERTURE IN THE LEFT MEMBRANA TYMPANI.

g, Handle of the malleus; *p*, Free remnant of the membrana tympani; *n*, Adherent cicatrix, extending from the posterior remnant of the membrana tympani to the inner wall of the tympanic cavity; *l*, Free margin of the cicatrix.

ear, and during the application of Siegle's speculum, feel hard when touched with a probe, it may be assumed with great probability that the cicatrix is united with the bony wall. Although some parts of the membrane do yield, it must not be concluded that no union exists between the depressed parts and the inner tympanic wall; this may be explained by the fact that sometimes the connective tissue causing the adhesion is stretched in the shape of a band between the membrane and the inner tympanic wall, and displays a certain amount of elasticity during the examination.

The diagnosis of such cicatrices is rendered more difficult if the cicatricial tissue is stretched in front of the tympanic orifice of the tube, or if the upper part of the sac is perforated, so that the air which has been forced through the Eustachian tube escapes freely into the external meatus. Under such conditions, the parts which are not adherent also remain immovable during the inflation of air into the tympanic cavity.

Where the defect in the membrane is large, we often find that only certain portions of the posterior (Fig. 212), inferior, or anterior remnants of the membrane become adherent to the inner tympanic wall by the formation of cicatricial tissue; when this is the case the diagnosis, as a rule, presents no difficulty.

The cicatrices which extend from the anterior margin of the perforation to the inner wall of the cavum tympani, and which form a septum between the tympanic orifice of the tube and the tympanum, are of special interest. The diagnosis of such a septum stretched before the orifice of the tube can be established with certainty only if one is able to see, through the perforation (Fig. 213), the deep-seated, dark-gray cicatrix, which is sharply demarcated from the inner tympanic wall; and, further,
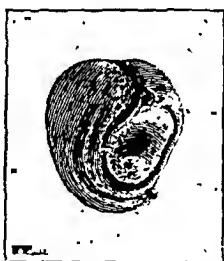
FIG. 213.—MEMBRANOUS SEPTUM BETWEEN THE TYMPANIC CAVITY AND THE EUSTACHIAN TUBE.

From a woman, 29 years of age, who suffered several years ago from suppuration of the middle ear. Hearing distance: Acoumeter = 5 cm. Speech = 2½ m.
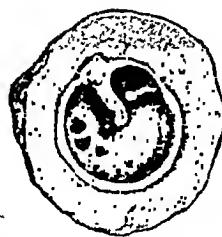
FIG. 214.—A SEPTUM BETWEEN THE EUSTACHIAN TUBE AND THE TYMPANIC CAVITY, WHICH IS RUPTURED IN THREE PLACES.

(From a specimen in the author's collection.)

if it is seen to bulge somewhat during the Valsalvan experiment, and to display a distinct mobility during examination with the Siegle speculum.

Such cicatrices sometimes become perforated in one or more places, whereby the air escapes freely into the external meatus; these perforations are probably caused by the repeated impact of the air while blowing the nose (Fig. 214). Such cicatrices are easily diagnosed, if a black orifice is visible behind the anterior ledge-shaped remnant of the membrane in the anterior part of the field of view (Fig. 215), through which bubbles filled with air or mucus make their appearance during the Valsalvan experiment. Just as in the Eustachian tube, so can the entrance into the mastoid antrum be occluded by a membranous septum, and become separated from the tympanic cavity.

In those cases in which the entire inner surface of the retracted or flattened, thickened, parchment-like membrane is adherent to the wall of the promontory, it appears whitish-yellow and opaque, and firm and non-resistant on probing. Sometimes,

when the membrane is totally adherent, one finds sharply-defined, groove-like depressions on it (Fig. 216), which are produced partly by the marked retraction of the cicatricial tissue and partly by band-like thickenings on the surface of the membrana tympani. The handle of the malleus is strongly drawn inwards and backwards by such bands (Fig. 216), and sometimes it is united so firmly with the incus and the stapes that the power of vibration of the ossicles is reduced to a minimum. The knowledge that such bands exist is of the greatest importance in the operative treatment of these cases.

The pseudo-membranes which develop in consequence of chronic middle-ear suppurations, the adhesions of the cicatrices of the membrane, and the immediate union of the remnant of the membrane with the inner tympanic wall, divide the middle

FIG. 215.—LARGE PERFORATION IN THE MEMBRANA TYMPANI.

The cicatrix, extending from the anterior remnant of the membrana tympani to the inner wall of the tympanic cavity, is perforated. From a woman, 48 years of age, who suffered for twenty-eight years from otorrhœa.

FIG. 216.—CICATRICIAL DEPRESSIONS AND BAND-LIKE THICKENINGS ON THE MEMBRANA TYMPANI.

From a young man, 19 years of age, who suffered in childhood from otorrhœa. Hearing distance for speech = $\frac{2}{3}$ m.

ear into a number of irregular spaces, which either communicate with each other or are completely separated (Fig. 217). Thus one finds in the author's collection specimens in which the tympanic cavity is divided into two parts by a vertical adherent scar running from the tympanic membrane to the inner tympanic wall; of these two parts, only the anterior one communicates with the Eustachian tube. Such cases are easily diagnosed in the living with the Siegle speculum. In other specimens the tympanic cavity is divided into an upper and lower part by a horizontal, thickened membrane stretching from the middle of the tympanic membrane to the promontory wall.

Small cavities in the tympanum may dry up, or they may be the seat of a mucous or purulent exudation, or they may form the place of origin of small cholesteatomatous masses; if these cavities lie within the field of view, they appear as white prominences from which, after they have been opened, the epithelial masses protrude. These partially isolated cavities are most

frequently found in the posterior superior portion of the tympanic cavity; they communicate only with a portion of the upper tympanic space or with the mastoid antrum, and are completely separated from the anterior part of the tympanic cavity. Such sacculated accumulations of exudate at the posterior superior quadrant of the membrane are seen as dark brown (viscid mucus) or greenish (pus) globular protuberances (Fig. 218), after the incision of which there is a discharge of the secretion. Such localized suppurations run a most tedious course, because it is difficult to bring about an aseptic condition of the seat of the process.

We must still mention those localized suppurative processes which are found at the posterior part of the upper tympanic
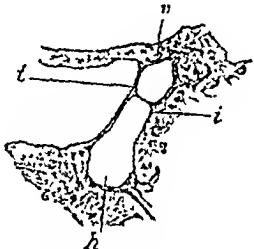
FIG. 217.—MEMBRANOUS BRIDGE EXTENDING FROM THE MEMBRANA TYMPANI (*t*) TO THE INNER TYMPANIC WALL (*i*).

v, Anterior; *h*, Posterior part of the tympanic cavity. Horizontal section through the left ear of a girl who died of general paralysis caused by a tumour of the brain, and who previously suffered from suppuration of the middle ear.
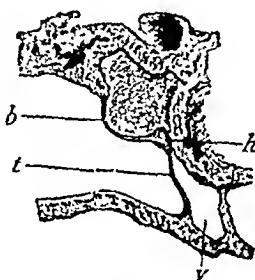
FIG. 218.—DIAGRAMMATIC SECTION THROUGH THE EXTERNAL MEATUS AND TYMPANIC CAVITY IN ORDER TO SHOW AN ENCAPSULATED EXUDATE IN THE POSTERIOR SPACE OF THE TYMPANIC CAVITY.

v, Anterior portion of the tympanic cavity; *t*, Membrana tympani; *h*, Adherent handle of the malleus; *b*, Posterior portion of the membrana tympani, bulged forward by exudate.

space and in the mastoid antrum. In these cases the septic secretion, which is generally of a curdy nature, is discharged into the external meatus through a small perforation in the posterior superior quadrant of the membrane, and the anterior portion of the tympanum is, at the same time, completely separated from its posterior part by the union of the anterior remnant of the membrane with the wall of the promontory (Fig. 219). These suppurations, which are often combined with caries of the incus, are characterized by their marked resistance to all therapeutic measures, and often necessitate more radical operative procedures. The same applies to those cases in which there is an adhesion of the superior remnant of the membrane and handle of the malleus to the promontory (Fig. 220), whereby the attic is completely or partially separated from the inferior tympanic space which communicates with the Eustachian tube.

Formation of Connective Tissue in the Tympanic Cavity.— The connective-tissue formations which develop in the tympanic cavity during the course of the adhesive processes and after an exhausted middle-ear suppuration exercise a great influence upon the disturbances of hearing. They arise from the growth of the round cells in the mucous membrane. Such connective-tissue masses, which are sometimes soft and yielding and at other times tough, and which entirely surround the malleus and body of the incus, are most frequently found in the upper tympanic space, in the mastoid antrum, and in the recesses of the oval and round windows. Occasionally one finds an atresia of the tympanic orifice of the Eustachian tube due to the formation of granulations and connective tissue. We may even find, as many of the author's specimens show, the entire cavum tympani filled with new-formed connective tissue.
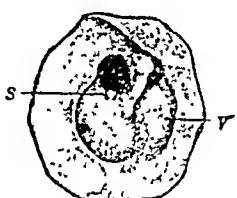
FIG. 219.—AN ADHERENT CICATRIX IN THE RIGHT MEMBRANA TYMPANI.

v, The anterior remnant of the membrane adherent to the promontory; s, Capitulum of the stapes, and above it an opening extending into the upper space of the tympanic cavity.
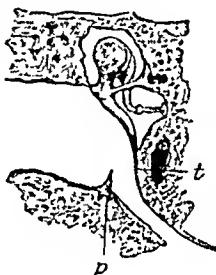
FIG. 220.—FRONTAL SECTION THROUGH THE EXTERNAL MEATUS AND THE TYMPANIC CAVITY.

p, Free ledge-shaped remnant of the membrana tympani; t, Place of adhesion of the upper margin of the perforation.

When these connective-tissue masses have existed a long time, they may ossify or calcify through the deposit of calcareous salts, and may lead to ankylosis of the ossicles and to occlusion of the oval and round windows. The appearances of the membrana tympani are most varied. Frequently, as previously described, the membrane is found partially or totally united with the inner tympanic wall, its adherent and cicatrized surface rough and uneven, the contour of the promontory sharply defined, and the adherent handle of the malleus projecting forward like a ledge.

The presence of connective-tissue or calcareous masses in the upper tympanic space can be assumed only from the marked disturbance of hearing; the same may be said of those products of disease embedding the malleus and incus, and which arise as the sequelæ of a suppuration of the middle ear. In cases in which there is a wide external meatus and a large space between

the promontory and the remnant of the membrane, are we in a position to inspect the different parts of the tympanic cavity by intratympanal otoscopy; this procedure is carried out with a small tympanic mirror, as recommended by Blake and Bing, or with the small metallic mirror of Botey (Fig. 221).

By means of this small mirror one is often able to detect adhesions between the handle of the malleus and promontory; to find changes on the malleo-incudal body, in the recesses of both windows, and on the posterior tympanic wall; and to see granulations at the tympanic orifice of the tube; furthermore, to detect the presence of a sequestrum in the attic, and to ascertain the extent and nature of the cavities containing cholesteatomata, as well as other defects in the temporal bone.
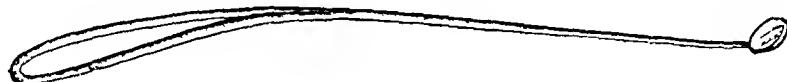
Fig. 221.

The disturbances of hearing which arise after adhesive processes of the middle ear vary according to the degree of obstruction to the conduction of sound in the ossicular chain and at the labyrinthine windows. The disturbance of hearing, however, is not always in proportion to the anatomical changes. The greatest deafness is observed with fixation of the malleus and incus through connective-tissue masses in the attic, with connective-tissue or calcareous fixation of the base of the stapes or of its crura, and with thickening of the membrane of the round window. If the adhesion is limited to that part of the membrane situated below the handle of the malleus, the acuteness of hearing may still be quite well preserved. On the other hand, however, the hearing is greatly influenced by the tension and rigidity of the new-formed bands in those cases in which the handle of the malleus is drawn so far inwards that it becomes united with the wall of the promontory, and in those cases in which the membrane has become united with the incus and stapes. It is only in such cases, however, in which the incudo-stapedial articulation has become disjointed through the suppurative process that the union of the membrane or its cicatrix with the stapes may be of advantage, since under such conditions the waves of sound are carried directly from the former to the latter.

III. Persistent Perforation in the Membrana Tympani.

Persistence of the perforation in the membrana tympani, after a suppuration of the middle ear has run its course, is especially met with in those extensive losses of substance which extend to the tendinous ring; still, one often finds small orifices in the membrane, which remain patent during the life of the patient.

The author's investigations show that the most frequent anatomical cause of the persistency of perforations is the growth of the epidermis of the external layer of the membrane over the margins of the orifice into the tympanic cavity (Fig. 222), thus preventing the formation of a cicatrix.

Every perforation which remains open for some time after the suppuration has ceased must not, however, be looked upon as
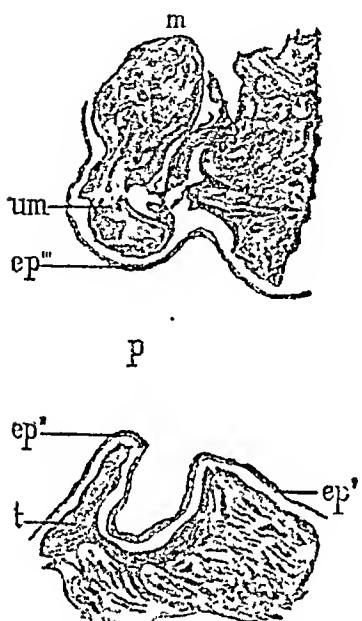
FIG. 222.—FRONTAL SECTION THROUGH THE MEATUS AND MEMBRANA TYMPANI AFTER A MIDDLE-EAR SUPPURATION, WITH PERSISTENT PERFORATION IN THE MEMBRANE.

m, Head of the hammer; *um*, Stump of the neck of the hammer; *t*, Lower part of the remnant of the membrane; *p*, Perforation in the membrane; *ep'*, Epidermis of osseous meatus; *ep''*, *ep'''*, Epidermis extending from the meatus through the opening into the cavum tympani.
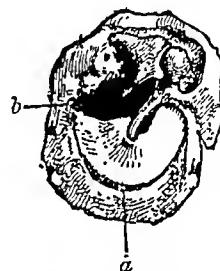
FIG. 223.—EXTENSIVE CALCIFICATION OF THE LEFT MEMBRANA TYMPANI, AFFECTING ALL ITS LAYERS. FROM A GIRL, 16 YEARS OF AGE, WHO DIED OF PULMONARY PHTHISIS.

a, The peripheral portion as well as a narrow strip in front of the handle of the malleus not calcified; *b*, Irregular defect in the posterior superior quadrant of the membrane. Membrana tympani and malleus rigid and immovable; connection between incus and stapes destroyed; the latter, however, completely movable. Similar changes also existed in the right ear. The patient could understand whispered speech in both ears from any part of a hospital ward 18 m. long.

persistent, because we sometimes meet with cases in which closure of the orifice by cicatrization ensues only several years after cessation of the purulent discharge.

Persistent perforations change in appearance from time to time. Sometimes the orifice diminishes to the size of a pin-hole, while at other times it enlarges after repeated attacks of the middle-ear inflammation even without a return of the otorrhœa. The opening not infrequently changes its location completely. In a

case in which there was a perforation in the membrane the size of a lentil below the handle of the malleus, a polyp was seen to project through the orifice; this was removed, and six months later the author found the membrane dry, with a large chalk deposit at the former site of perforation, and a round opening the size of a pin-head at the posterior superior quadrant of the membrane. In like manner one not infrequently finds at a subsequent examination chalk deposits, atrophic depressions, and adhesions on the remnant of the membrane, of which there were not the least traces at the previous examination.

In reference to the hearing function in persistent perforations, observations show that whispered speech can be understood at some distance with large defects in the membrane, even if the malleus and incus are exfoliated, or if the hammer has become fixed owing to an almost incomplete calcification of the remnant of the membrane (Fig. 223); this applies, however, only to those cases in which the foot-plate of the stapes is movable in the oval window, and in which the membrane of the round window is not thickened. Hearing is accomplished, in these cases, by the direct transmission of the waves of sound to the windows of the labyrinth. When we find that the hearing is well preserved in persistent perforations, we can conclude that no obstacles to the conduction of sound were created at the labyrinthine windows by the suppurative process. Marked disturbances in the hearing, with large defects of the membrane, are brought about either by the presence of contracted masses of new-formed connective tissue at the labyrinthine windows, or by the retraction and adhesion of the handle of the malleus; these conditions cause the long process of the incus to exert a certain pressure upon the stapes, whereby it is forced inwards and fixed in this position. This is a frequent cause of marked deafness in persistent perforations, and it is well to know this, as we can bring about a striking improvement in hearing by the removal of this constant pressure upon the stapes.

The power of hearing in the so-called dry perforations is not subject to such marked variations as is seen in the exudative stage of the process; nor do these variations show, on the whole, that progressive character as is observed in the chronic adhesive processes running their course without perforation. We not infrequently find that the disturbance of hearing remains stationary for years after suppuration has ceased, and even may stay so during the life of the individual. Frequently, however, one also observes, especially in old people, a diminution in the hearing which is either progressive or intermittent, and which finally leads to total deafness. Such a disturbance is caused by the constantly increasing rigidity of the newly-formed connective tissue and ankylosis of the ossicles, and by the secondary changes in the labyrinth, to which reference will again be made under Diseases of the Auditory Nerve.

IV. The Desquamative Processes and the Formation of Cholesteatomata in the Ear in Chronic Middle-Ear Suppurations.

In the chronic middle-ear suppurations, excessive production and desquamation of epithelial cells take place in the mucous membrane of the middle ear, and particularly in the external meatus. For this reason the secretion almost always contains, in addition to pus cells, epithelial cells in larger or smaller masses.

If the production of epithelium is not excessive, and there is no great obstruction to the flow of pus mixed with the epithelium, the process may continue for years without causing an accumulation of epithelium in the middle ear. On the other hand, where, during the suppuration, the desquamation of the proliferating epithelium is excessive, so that it pushes its way from the external meatus into the tympanic cavity through the perforation, the epithelial masses form large white or yellow lumps, which collect in the cavum tympani and external meatus. In addition to this excessive epithelial desquamation, we find that it is especially the obstructed flow of the secretion which favours the accumulation of epithelial lumps in the deeper parts of the ear. The following conditions hinder the free discharge of this secretion: A narrowing of the external meatus, multiple formation of polypi, adhesions between the membrana tympani and the inner tympanic wall, and the formation of sacculated spaces in the tympanic cavity. In cases of small perforations in the posterior superior quadrant of the membrane, and in Shrapnell's membrane, the secretion is of a curdy nature, and contains small lumps of epithelial cells.

The formation of such retention masses may go on for years without causing any special symptoms. Sometimes larger masses are discharged spontaneously, giving rise to severe pain. Not infrequently after these products have been retained for a long time they break down into a smeary, foul-smelling mass, consisting of granular detritus with numerous cocci. Such a degeneration is brought about by the action of the bacteria of putrefaction, and may sometimes lead to ulceration of the bone, with a fatal termination. One very frequently finds these decayed masses at the *post-mortem* examination of those cases in which death was occasioned by a cerebral complication, or sinus phlebitis owing to caries or necrosis of the temporal bone.

In addition to those structureless incoherent masses of desquamation which take their origin from the external meatus and middle ear, we often observe the growth of circumscribed tumours which are covered with a glistening mother-of-pearl pellicle, and which are composed of a homogeneous mass, or of concentric stratified lamellæ. These tumours, which present the form, appearance, and structure of cholesteatomata in other organs,

begin to develop either during the time of suppuration or after the process has run its course. The term ' cholesteatoma of the ear ' has been introduced into otology as an appropriate name for these tumours,. as well as for those structureless accumulations of epidermis which have been previously mentioned.

The lining membrane of the cavities in the temporal bone, which have become enlarged by the growth of the cholesteatoma, presents a tendon-gray, smooth, shining, mother-of-pearl appearance, and is covered with a layer which is firmly united with the bone, and resembles the rete Malpighii. The superficial cellular layer of this lining coat consists of polygonal, non-nucleated, squamous cells, which go to form the cholesteatoma (Steinbrügge and Kuhn), and through the further production of which the onion-like, stratified cholesteatoma is developed. Kirchner (*A. f. O.*, vol. xxxi.) found on sections of the bony wall surrounding the matrix that the cholesteatomatous masses forced their way into the Haversian canals, which explains the reason for the obstinate relapses of cholesteatomata even after the operative opening up of the middle-ear spaces.

That cholesteatoma in the ear has been long known to pathologists is seen from the writings of Cruveilhier,* Rokitansky,† Virchow,‡ and others. There is still, however, a great diversity of opinion in regard to the origin of these accumulations of epidermis. Virchow (*loc. cit.*), Mikulicz,§ and Küster|| explain the occurrence of cholesteatoma in the temporal bone as a heteroplastic formation; v. Tröltsch¶ regards it as a retention tumour; Wendt** as the product of a desquamative inflammation of the mucous membrane of the middle ear; while Bezold†† and Habermann‡‡ consider it the result of the inward growth of the epidermis of the external ear through the perforation of the membrane into the tympanic cavity. Leutert§§ distinguishes a real tumefaction and cholesteatoma, brought about by the implantation of the remnants of the tympanic membrane, which are covered with epidermis.

Primary cholesteatoma in the temporal bone is, on the whole, very rare. Virchow's investigations leave us in doubt as to whether these heteroplastic tumours, embedded in the petrous bone, penetrated the tympanic walls during their growth, or whether they arose primarily in the middle ear, and had worn away the bone through constant pressure. Lucæ|||| observed a rare case of primary cholesteatoma, in which the growth took its origin from the mucous membrane of the tympanic cavity, and in which there were no traces of a suppurative inflammation, nor of a perforation of the membrane. Erdheim adds two more cases, in which there were absolutely no signs of immigration. Kuhn¶¶ describes a case of primary cholesteatoma in a man, fifty-one years of age, who had suffered for one year from tinnitus, dizziness, and hardness of hearing. This patient caught a cold, upon which a suppurative inflammation of the middle ear developed with marked reactive symptoms, great pain, and the formation

* *Anatomie pathologique*, T. II.
† *Lehrbuch d. patholog. Anat.*, vol. i., p. 121.
‡ *Archiv*, 1885, vol. viii., p. 371.   § *Wien. med. Wochenschr.*, 1879.
|| *Verh. d. Berl. med. Ges.*, 1899.   ¶ *Arch. f. Ohrenh.*, 1868.
**- *Arch. f. Heilk.*, vol. xiv.   †† *Zeitschr. f. Ohrenh.*, 1889, vol. xx.
‡‡ *Arch. f. Ohrenh.*, vol. xvii.   §§ *Arch. f. Ohrenh.*, vol. xxxix.
|||| *Verh. d. Berl. med. Ges.*, 1886.   ¶¶ *Zeitschr. f. Ohrenh.*, vol. xxi.

of an abscess in the mastoid process. Opening up of the mastoid revealed the presence of a cholesteatoma the size of a hen's egg, after the removal of which a cavity was discovered about the size of a child's fist, in which the exposed sigmoid sinus and a portion of the anterior inferior lobe of the cerebellum with its intact covering could be seen. Körner (*Zeitschr. f. Ohrenheilk.*, vol. xxxvii.) reports a case of primary cholesteatoma twice the size of a hen's egg, which broke down into pus owing to an acute middle-ear suppuration, and which extended from the petrous bone to the torcular Herophili. It, furthermore, pressed the inferior portion of the occipital lobe and cerebellum low down, and caused the occipital and squamous bones and the base of the pyramid of the petrous bone to become destroyed through constant pressure.

Clinical and pathological observations have shown beyond a doubt that the formation of cholesteatomata of the ear is secondary in the great majority of cases. .Even if it must be admitted that secondary cholesteatomata are very often caused by the entrance of the epidermis of the external meatus into the middle ear,* the author is, however, of the opinion, based on the observation of a considerable number of specimens in his collection, that they may develop primarily in the middle ear itself. This applies especially to the cholesteatomata in the mastoid antrum and cells (Rohrer).† The fact that non-nucleated squamous cells are very often present in these masses speaks in favour of this.

The independent development of epidermic elements in the tympanic cavity and in the mastoid process can take place only if the mucous membrane of the middle ear has become epidermized. In the author's opinion, the dermic transformation of the mucous membrane, which has become greatly changed in structure, usually takes place through the continuity of the lining membrane of the middle ear and external meatus, which has been brought about by the growth of the epidermis of the external meatus, with its rete Malpighii, into the tympanic cavity through the perforation in the drum.

The mere invasion of the epidermis of the external meatus into the tympanic cavity does not in itself lead to the formation of cholesteatomatous masses. This is shown by the epidermic blind pouches first described by Schwartze,‡ and also observed by the author in a vast number of specimens. These pouches extend from the external meatus into the cavum tympani and mastoid antrum, and may persist as such during the entire life of the patient. The inward growth of the epidermis of the external meatus towards the tympanic cavity, without the formation of cholesteatomata, takes place more often than is generally supposed. This is evident from the many specimens of

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* Rohrer, *Contribution à la Pathologie du Cholesteatome de l'Oreille.* Revue de Laryngologie et d'Otologie du Dr. Moure, 1892.

† According to Leutert, also by growth into the bone-cells which have been opened by operative procedures.

‡ *Pathologische Anatomie des Ohres,* 1878.

exhausted middle-ear suppurations with extensive perforations of the membrane which the author has had occasion to examine, and in which no trace of an accumulation of epidermis in the tympanic cavity was seen macroscopically, but in which he could show microscopically in serial sections that the epidermis of the external meatus had extended to the inner tympanic wall. The invasion of the epidermis of the meatus into the middle ear leads to the secondary formation of cholesteatomata only when there is an excessive growth of epidermis in the external auditory canal, which is associated with a marked desquamation of the lining membrane of the middle ear.

The membranous or bony closure of the tympanic orifice of the Eustachian tube, which sometimes takes place during the course of a suppuration of the middle ear, is another factor which is conducive to the invasion of the epidermis of the external meatus into the tympanic cavity. If the communication between the naso-pharynx and the tympanic cavity is interrupted through closure of the tube, the epithelium of the middle ear loses its power of resistance, and is easily pushed aside by the invading epidermis of the external meatus.*

It is found that the larger the defect in the membrana tympani, the more easily does the epidermis of the external meatus force its way into the middle ear. Where the perforation is centrally located, the invasion is rendered more difficult than if it were at the periphery. This is shown by the more frequent occurrence of cholesteatomata in cases in which small perforations are situated in the posterior superior quadrant of the membrane or in perforations of the pars flaccida (Morpurgo, Bezold). According to the author's observations, cholesteatomata are seldom met with in the middle ear when the peripheral perforations are located in the anterior inferior quadrant of the tympanic membrane.

With perforations of the pars flaccida the invasion takes place the more easily, because a more highly developed band of cutis and epidermis extends from the superior wall of the meatus to the membrana tympani; in other words, a more intensive growth of epidermis is found at this part than in other parts of the meatus.

The path of invasion of cholesteatomata is not always through the perforated membrane. In a case described by the author (*loc. cit.*) of cholesteatoma in the mastoid, he could demonstrate the entrance of the epidermis into the spacious cells through a fistula in the cortical layer of the mastoid and through a second fistula in the posterior wall of the meatus.

The size of cholesteatomata varies from a hemp-seed to that of a walnut and over. Their form is round or oval; they may correspond to the concavities of the middle ear, or they may show a very irregular outline, in conformity with the cavities in the temporal bone which have been produced by the destruction and

* A. Politzer, *Das Cholesteatom des Gehörorgans vom anatomischen und klinischen Standpunkte. Wien. med. Wochenschr.*, 1891, 8-12.

absorption of the bony tissue. The surface, which is usually iridescent, is smooth or glandular, with club- or nipple-shaped projections. The masses sometimes show on cross-section a stratified, laminated, iridescent structure of various colours, occasionally present the appearance of freshly-made cheese, and at times have a degenerated core.

They consist of large, round or polygonal, often non-nucleated, squamous, epithelial cells, with the addition of granules, giant cells, fat globules, cholesterin crystals, and bacteria. Caseated exudate or semi-fluid masses of detritus are occasionally found alongside of, and between, the epithelial masses.

Cholesteatomata are most frequently located in the mastoid antrum, mastoid process, the upper tympanic space, and the external attic. Circumscribed accumulations in the cells bordering on the walls of the meatus and in the squamous portion of the temporal bone are of rare occurrence.

Cholesteatomata may attain a considerable size without the least sign of caries or absorption of the temporal bone. Sometimes, however, when there are small or large tumours, one finds, in addition to an extensive ivory-like sclerosis, defects and excavations in the bone; these are produced partly by the continuous pressure of the masses, and partly by atrophy of the bone, which is associated with a pathological change in the lining membrane of the middle ear. Frequently, however, defects are found in the temporal bone before the formation of the cholesteatoma, which are brought about by carious destruction or exfoliation of necrotic bone, and which may become larger by the growth of the cholesteatoma.*

Defects of this class most frequently involve the margo tympanicus of the temporal bone, a large part of the posterior and superior walls of the osseous meatus, and the mastoid process.

We therefore often meet with a very extensive loss of substance in the temporal bone, through which the tympanic cavity, the external meatus, and mastoid process are converted into one common, irregular cavity. Sometimes a portion of the petrous bone is also involved in the process.

Symptoms.—Accumulations of cholesteatomata in the temporal bone may exist for years without giving rise to any symptoms. They often cause a feeling of heaviness and pressure in the corresponding side of the head, headaches, and dizziness, without the presence of any inflammatory phenomena. Owing to some external influence, as, for example, the entrance of fluids into the external meatus, an inflammatory condition

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* Cp. Biehl, *Wien. klin. Rundschau*, 1898; Moses, *München. med. Wochenschr.*, 1898; Grunert, *Berl. klin. Wochenschr.*, 1893; Steinbrügge, *Z. f. O.*, Bd. viii. and ix.

is produced in the deeper parts of the temporal bone, with very severe reactive phenomena due to the rapid swelling of the epidermic masses; this may lead either to the spontaneous expulsion of the cholesteatoma through the perforation in the membrane, with complete disappearance of the troublesome symptoms, or to a penetration of the mass into the cranial cavity, ending fatally with meningeal symptoms. The inflammations of the attic and mastoid process produced by the cholesteatoma are often accompanied by a sinking of the posterior superior wall of the meatus.

Terminations—(1) Spontaneous Expulsion of the Mass.— This is occasioned by the rapid swelling of the mass, and by the pressure of the fluid secretion behind it. The mass reaches the external meatus either through the perforation in the membrane or through a defect of the bone in the posterior wall of the meatus; it rarely forces its way through the Eustachian tube into the naso-pharynx or, after destruction of the anterior wall of the meatus, into the maxillary joint. The cholesteatoma may also perforate the outer covering of the mastoid process with the symptoms of an abscess. Jansen has repeatedly observed with cholesteatoma, a fistula in the horizontal semicircular canal.

(2) **Death.**—(*a*) Through pyæmia in consequence of bacterial infection of the secretion lying behind the cholesteatomatous masses. This termination may take place as the result of a septic ostitis alone, without the least sign of a necrotic condition of the temporal bone.

(*b*) Through meningitis, brain abscess, erosion of the sigmoid sinus or jugular fossa with sinus phlebitis and otorrhagia. These complications are brought either by caries and necrosis of the temporal bone, which are associated with the formation of the cholesteatoma, or by the immediate perforation of the mass through the roof of the tympanum and mastoid, or through the posterior wall of the petrous bone towards the cranial cavity.

Diagnosis.—The diagnosis of cholesteatomatous accumulations in the middle ear can be made with certainty only when the whitish-yellow epidermal masses can be seen in the external meatus or in the lower part of the tympanic cavity. In cases of large perforation of the tympanic membrane the small whitish-yellow epidermic masses* which protrude from the upper remnant of the drum are important in making the diagnosis of cholesteatoma in the attic or antrum. The diagnosis in such cases is substantiated by the marked growth of epidermis in the external meatus, which can be traced as far as the tympanic cavity. Cholesteatoma in Prussak's space can be diagnosed by the appearance of a white mass in the perforated Shrapnell's membrane, which feels doughy on probing. The frequent

* Politzer, *Atlas*, Plate XIV., 25-26.

appearance of small gritty lumps or large whitish-yellow strings in the water after syringing indicate the presence of caseated or cholesteatomatous masses in the middle ear; these accumulations can be ground up with the fingers, possess a foul odour, and show under the microscope pus, cocci, fatty degenerated epithelium, and cholesterin crystals (Alexander). The diagnosis is substantiated if these characteristic, granules and lumps reappear repeatedly in the secretion for several days after the middle ear has been thoroughly cleansed. The author usually found this peculiarity of the secretion in protracted and obstinate suppurations which were not profuse, and in perforation of Shrapnell's membrane; furthermore, in adhesions between the membrane and wall of the promontory where the secretion could escape only through a small fistulous opening in the posterior superior quadrant of the membrane, in protracted suppurations of the mastoid antrum, and in fistulous openings in the osseous meatus. Chronic middle-ear suppurations in lymphatic and tubercular individuals present a secretion of a similar nature.

On the other hand, the diagnosis cannot be made in those cases in which circumscribed cholesteatomata, surrounded by a delicate covering, are embedded in the mastoid process, or are situated in the upper tympanic space. The presence of such tumours in the deeper parts is often discovered only when they begin to break down in the course of treatment, inasmuch as small pieces are usually expelled through the perforation of the membrane, or they bore through the cortical layer of the mastoid process. Where the desquamation in the middle ear can be demonstrated, and especially where a continuous expulsion of the before-mentioned gritty lumps and often-recurring pains in the mastoid are noticed, we can conclude · with certainty that there is a cholesteatoma in the mastoid process. This is· an important indication for the operative opening up of the mastoid.

Prognosis.—The prognosis of cholesteatoma depends on its location, its extent, and on the changes in the ear. Cases are exceedingly rare in which a permanent cure is obtained after spontaneous expulsion of the mass or after conservative treatment. In many cases cure is not attained until the middle-ear spaces have been laid open by operative measures, and even this is not always successful. According to Bezold (*Z. f. O.*, vol. xiv.) and Grunert (*A. f. O.*, vol. xl.), relapses are less likely to occur when the cavity containing the cholesteatoma is very large and exposed to the external atmosphere through a wide opening in the meatus or in the mastoid process.· As a rule, a cholesteatoma must be regarded, on account of its frequent relapses, as a serious sequela of a suppuration of the middle ear. The causes of these relapses during the time of suppuration may be attributed to an obstruction which prevents the secretion from

being discharged, to the continuous desquamation in the external and middle ears after cessation of the suppuration, and to the extension of the epithelial growth into the bone spaces of the tympanic walls. In some cases the invasion of the epidermis into the tympanic cavity forms blind sacs, which persist without giving rise to any complications; in other cases, however, in which there may or may not be symptoms of suppuration, there is a gradual or rapid expulsion of the thickened epithelium in the form of flat sheaths and an accumulation of the cholesteatomatous mass, which rapidly fill the cavities of the temporal bone. In those cases in which inspection reveals a middle-ear suppuration with desquamation, we must not conclude that a cure has been obtained by the cessation of the discharge, as headache, dizziness, or pyæmic symptoms often arise suddenly some weeks or months later; where such phenomena present themselves, and where the degenerated cholesteatomatous masses in the antrum and mastoid process are the causes of these threatening symptoms, the radical mastoid operation is indicated.*

For the treatment of cholesteatoma the reader is referred to the section on Treatment of Chronic Suppurations of the Middle Ear.

We must also make a few remarks here on the formation of crusts in the external and middle ears. In those cases in which the discharge is slight, they develop as the result of the drying up of the secretion which has been allowed to remain. The brownish-green crusts, which are often in the shape of small tubes, usually lie in the inner portion of the osseous meatus and on the remnant of the drum, and not infrequently extend into the tympanic cavity. They are sometimes so adherent that they can be removed only with difficulty with a blunt probe. Occasionally the middle-ear suppuration subsides with the formation of a crust, which remains adherent for a long time, and which is cast off spontaneously. Often, however, the suppuration continues under the crust, and one finds, after its removal, a purulent surface which is occasionally covered with granulations. Crusts which form in the deeper parts of the ear after the suppuration has run its course must, therefore, always be removed (*vide* Treatment). Small perforations are sometimes occluded by plug-like crusts, and are thus prevented from closing.

Small, dry, firmly-adherent crusts are observed now and then at the base of retracted, adherent cicatrices of the membrane. They are frequently noticed in cicatricial retractions of Shrapnell's membrane, and on cicatrices in the posterior superior quadrant of the membrane, which are united with the incudo-stapedial articulation, or with the head of the stapes which has

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* A review of the present theory as to the development of cholesteatoma is found in Grunert, *München. med. Wochenschr.*, 1904; and Dölger, *Die Mittelohreiterungen.* München, 1903.

become separated from the incus. The removal of such crusts is important, as the author has repeatedly seen a striking improvement in the hearing follow.

Prognosis of Chronic Middle-Ear Suppuration.—The prognosis of chronic middle-ear suppuration is generally uncertain, for, as long as the suppurative process continues, we cannot positively foretell what the termination will be. However, the prognosis depends on such important data as the cause of the disease, the local changes in the external and middle ear, and the general condition of the patient.

The prognosis is favourable in the uncomplicated forms, and in healthy, robust individuals. The following local changes in the middle ear may be regarded as favourable prognostic signs: Defects in the membrana tympani which are centrally located, and not peripheral perforations in the anterior inferior quadrant; a smooth, non-granulating mucous membrane of the tympanic cavity, which is not much thickened and has no epidermal layer upon it; a permeable Eustachian tube; and a moderate, non-fœtid purulent discharge.

The prognosis is less favourable, on the other hand, in those middle-ear suppurations arising in the course of scarlet fever, measles, influenza, typhoid, scrofula, syphilis, diabetes, leucæmia, and other forms of cachexia, and in those cases associated with chronic naso-pharyngeal affections, adenoids, and tonsils. Unfavourable prognostic local changes are: Profuse blennorrhœic or protracted fœtid secretion, peripheral defects in the posterior superior quadrant of the membrane, perforation of Shrapnell's membrane, excessive growth of the middle-ear mucous membrane, with extensive formation of granulations (aural polypi); furthermore, a whitish-gray epidermal layer on the promontory wall, polypoid degeneration of the membrana tympani, ulceration of the lining membrane and bony walls of the middle ear, marked stricture of the Eustachian tube, cholesteatomatous formation in the middle ear, paresis and paralysis of the facial nerve, and, finally, strictures and ulcerations in the external meatus. According to Körner, the frequent return of intercurrent inflammations is an unfavourable prognostic sign.

It is difficult to determine, in the exudative stage, the prognosis as to the improvement in hearing. This may be explained by the fact that the disturbance of hearing is not always caused by permanent changes in the sound-conducting apparatus, but may be due to simple swelling of the mucous membrane covering the ossicles and labyrinthine windows, which may almost entirely subside after cessation of the suppuration. As a rule, however, we are justified in giving a more favourable prognosis in those cases in which the disturbance of hearing is slight, or in which a striking improvement is obtained after an inflation of air into the middle ear, than in those cases in which the greatly reduced

hearing power undergoes only a slight alteration after the Eustachian tube has been rendered permeable. The prognosis is worse where there is an exfoliation of the ossicles, a marked stricture of the meatus leading to its occlusion, and closure of the tympanic orifice of the Eustachian tube.

The prognosis as to the hearing after cessation of the discharge is most favourable where only a slight disturbance in the hearing remains after cicatrization of the perforation; it is unfavourable, however, in those cases in which there is a marked diminution in the hearing after closure of the perforation, as from this fact it may be concluded that there is a hindrance to the conduction of sound at the malleus or incus.

Where the perforation remains patent, the prognosis is more favourable if the hearing distance remains stationary in spite of the long duration of the process; it is unfavourable, however, if, after cessation of the suppuration, a marked deafness remains which does not show any change after the Eustachian tube has been rendered permeable, after pneumo-massage, or after the application of an artificial membrana tympani. The prognosis is worse if the deafness is progressive, and if it is associated with continuous subjective noises and with a shortened perception for the tone of the tuning-fork through the cranial bones (Schwabach).

The Treatment of Chronic Middle-Ear Suppuration.

The treatment of chronic middle-ear suppuration depends principally on the objective changes in the ear. In cases in which inspection shows merely a swelling of the mucous membrane without signs of caries of the tympanic walls, the treatment is different from that employed in cases in which one finds polypi and granulations in the tympanic cavity, or on the remnant of the membrane, or in which examination reveals a caries of the temporal bone, or cholesteatomata in the middle ear. The former should be designated as an uncomplicated, the latter as a complicated otitis. That the method of treatment is subject to many modifications, depending on the quality and quantity of the discharge, on the location and size of the perforation in the membrane, on the secondary changes in the external meatus, and on the general condition of the patient, will be seen from the following paragraphs.*

The secretion of this form of disease is always septic on account of its stagnation in the cellular accessory cavities of the middle ear, and its infection with putrefactive bacteria. This is the reason why we so often find a diseased condition of the temporal

* Cp. G. Field, Harveian Lectures, *On the Pathology and Treatment of Suppurative Diseases of the Ear*, 1892; V. Grazzi, *Manuale d. Otologia*, Firenze, 1890; L. Sune y Molist, *La Otorrea en general*. Tratamiento, *Rev. Otologica de Alcalá de Henares*, 1883.

bone leading to severe complications. Considering the construction of the temporal bone, which is so favourable for the development of necrotic processes, one would expect serious complications much more often. The reason for this is that during the suppuration, the pneumatic spaces of the temporal bone are obliterated by the formation of granulation tissue, whereupon the discharge of pus ceases.

The main objects in the local treatment of this disease are, first, to diminish the inflammatory conditions of the mucous membrane of the middle ear, thereby arresting the purulent discharge; and secondly, to prevent the development of serious complications. These are accomplished by the removal of all obstacles which favour the stagnation of the secretion in the middle ear, by the mechanical removal of the secretion, and by the application of medicaments to the mucous membrane which will arrest the discharge. When this conservative treatment does not bring about the desired effect, we may justly resort to operative measures.*

The secretion is removed from the middle ear by inflations of air *per tubam*, combined with rarefaction of the air in the external meatus. The author's method of inflation proves advantageous in the great majority of cases. Catheterization should be employed only if there are marked obstructions to the entrance of air into the middle ear, owing to great swelling of the mucous membrane of the tube, or to granulations, polypi, and products of desquamation in the tympanic cavity and in the meatus.

Through the inflation of air *per tubam* the secretion is often only forced out of the tube and anterior portion of the tympanic cavity into the external meatus, while the pus lying in the posterior part of the middle ear and mastoid antrum is hardly affected by the current of air. The author has therefore used, in the last few years, the combination of inflations through the Eustachian tube and the rarefaction of the air in the external meatus in the treatment of chronic middle-ear suppurations. By rarefaction of the air in the external meatus it is often possible to aspirate a large quantity of secretion from the middle ear into the canal, which cannot be accomplished by the air-douche alone.

The secretion which has been forced out of the middle ear is then removed by irrigation. When the obstruction in the Eustachian tube is slight, the injected fluid is sometimes forced back into the pharynx, whereupon it is expelled through the nose. Sometimes marked dizziness is caused by the sudden increased pressure of the injected fluid against the labyrinthine windows; this dizziness can also be brought about by merely

* E. Bloch, *Die operative Behandlung der Mittelohreiterungen. München. med. Wochenschr.*, 1897.

irrigating the ear with tepid or warm water owing to a stimulation of the labyrinthine fluid. When this does occur, we must stop the irrigation, whereupon the parts soon return to their normal state. When, however, the vertigo is very severe, it can be readily relieved by an inflation of air by the author's method, or by the rarefaction of the air in the external meatus. Where the otorrhœa is profuse, the ear should be syringed every two or three hours, and less frequently as the charge diminishes.

Syringing the ear in chronic middle-ear suppurations is of great importance. This can be seen from the fact that very often one finds at the first examination of neglected cases a thickened, foul-smelling mass of secretion which is infiltrated with vibriones and bacteria, after the removal of which granulations and polypoid growths are found on the remnant of the membrane, or on the tympanic mucous membrane.

Various solutions may be used for syringing as long as they have cleansing and antiseptic properties. Ordinarily, a sterile saline solution or a boracic acid solution at a temperature from 90° to 95° F. is sufficient. When the discharge is profuse and foul-smelling, it is well to add some stronger antiseptic solution, as lysol, permanganate of potash, zonite, etc. Where the discharge is profuse and blennorrhœic in character, the author has seen a rapid diminution and cessation follow the use of a 0·3 litre of warm water, to which 4–5 drops of the oil of turpentine have been added (not spirit of turpentine).

The fluid which remains behind in the deeper parts of the ear after syringing must be removed with small, sterilized, cotton tampons in order to obtain a clear view of the deeper structures. Carefully cleansing the ear, without any other medication, is frequently all that is necessary to arrest the suppuration. In some cases of chronic middle-ear suppuration, however, syringing is harmful, as the injected fluid often acts as an irritant, causing the discharge to continue. When irrigations are stopped, one soon notices an improvement in that the suppuration gradually diminishes and often ceases entirely. In many cases, however, the discharge can be arrested only by the application of drugs.

The medicaments are employed either in the form of solutions or powders. Fluids should always be slightly warmed before instillation. Solutions which have not been warmed often cause pain and attacks of dizziness. When the perforation in the membrane is large, the fluid can easily reach the tympanic cavity, so that the mucous membrane is bathed to a large extent. With small perforations, on the other hand, when the entrance of the fluid into the middle ear is prevented, it is recommended to press the tragus over the external auditory orifice in an inward direction, whereby the medicament is forced into the middle ear. By this manipulation a portion of the fluid occasionally escapes through the Eustachian tube into the pharynx. In cases in which the perforation is situated at the anterior portion of the

membrane, and in which we wish the medicament to reach the posterior parts of the middle ear during this manipulation, the head of the patient must not only be inclined to the opposite side, but also somewhat backwards. Instead of this procedure, we can resort to another measure. This consists in filling the external meatus with the medicated fluid, inclining the head of the patient to the opposite side, and then giving an inflation of air after the author's method. By doing this, the middle ear is cleansed, and the stagnant secretion is driven from the deeper parts.

In using powders, we must be particularly careful that they come into immediate contact with the secreting surface. For this purpose we employ a suitable powder-blower, with which the medicament can be readily insufflated. We insufflate only a small amount, as the free discharge of secretion may be hindered if too large a quantity is applied. In order that the patient may treat himself—namely, by insufflating the powder with his mouth—it is convenient to use a quill rounded at the end and attached to a short rubber tube; this quill is filled a quarter of its length by dipping it several times into the pulverized medicament. The end of the quill is then inserted into the external canal while the rubber tube is held in the patient's mouth. If the patient now blows into the tube, the powder is forced into the middle ear.

1. **The Antiseptic Treatment.**—The antiseptic treatment of chronic middle-ear suppuration has proved to be superior to all other methods of treatment. That the antiseptic method of treatment is very often ineffectual in caries, in cholesteatomata, in abundant granulations in the accessory cavities of the middle ear, or in accumulations of pus in the temporal bone which cannot be reached, and that these conditions can be cured only by operative means, is readily appreciated. This is by no means sufficient ground, however, for depreciating the therapeutic value of antiseptics in the treatment of chronic middle-ear suppuration.

The following antiseptic medicaments have proved most advantageous in the treatment of chronic middle-ear suppuration:

(1) *Hydrogen Peroxide* (Rohrer, Bull, Börne-Bettman, G. Gellé, and Brühl).—The pure peroxide of hydrogen has been used for years as an excellent antiseptic in treatment of chronic middle-ear suppurations. The lukewarm fluid which is poured into the meatus is rapidly decomposed when it comes into contact with the secretion (still more with blood), whereupon the oxygen escapes into the external meatus with the excessive formation of bubbles. According to Rohrer, particles of secretion lying in the lateral cavities of the tympanum are thus brought to the surface, which cannot be reached by syringing. According to the author's experience, there is always more or less reaction in the formation of air bubbles when the peroxide comes into

contact with the purulent secretion, so that one finds that the formation of froth is generally more abundant the greater the suppuration. A gradual diminution in the formation of bubbles in the course of treatment may be regarded as a sign indicative of the abatement of the discharge.*

The author would still like to mention a method of treatment which he has used for the last few years, and which has proved of value in a number of obstinate cases of middle-ear suppuration. It consists in first giving an inflation of air, thoroughly syringing the ear, and then drying it with cotton pledgets, whereupon the external meatus is filled with warm peroxide of hydrogen. The olive-shaped nozzle of a rubber tube, which is attached to a small rubber air-bag, is then introduced almost hermetically into the external auditory orifice, and the air alternately rarefied and condensed. By this procedure—as experiments with carmine solution on anatomical specimens show—the fluid is driven into the more distant spaces of the cavum tympani, a portion of the secretion lying there is forced out, and the middle ear is more thoroughly cleansed than by any other manipulation.

In non-complicated cases it is often possible to arrest the middle-ear suppuration after the use of hydrogen peroxide for eight to fourteen days. In some cases the effect of hydrogen peroxide may be increased by the addition of boracic acid $(1 \cdot 0 : 40 \cdot 0)$ or alcohol $(10 \cdot 0 : 40 \cdot 0)$. If no decided diminution in the secretion is noticed after the repeated use of the peroxide, we may combine this method of treatment with the insufflation of a small quantity of boracic acid.

(2) *Boracic Acid.*—Boracic acid has proved to be, in many cases, a splendid drug in arresting the purulent discharge (for the method of applying it, see p. 366). Where the secretion is abundant, the powder is insufflated once a day; where, however, it is light, every second or third day suffices. In exceptional cases the suppuration ceases even after two or three applications. As a rule, however, the effect is gradual, and cure is often obtained only after this drug has been employed for several weeks. In some cases the finely pulverized sodium tetraboricum or sodium boracic. works very well, either alone or with equal parts of boracic acid. In using boracic acid, we should not apply it too freely if the discharge is abundant or of a thick tenacious character, as it causes the secretion to become caky and prevents its free discharge.

Boracic acid is of less value when the discharge is of a mucous nature; still, the author has occasionally had good results when the powder was combined with the oil of turpentine (acidi borici præcip., 5·0, ol. terebinth.

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* Neumann recommends pouring a solution of potassium permanganate into the ear before the instillations of peroxide of hydrogen; the formation of gases which is thus caused is very beneficial in cleansing the middle-ear spaces.

gtt. 5). When the secretion is of a septic nature, boracic acid produces a better effect if a few drops of carbolic acid are added (acidi borici præcip. 5·0, acidi carbolici, gtt. 5). On the other hand, the powder often proves insufficient, and even harmful, in excessive growth of the mucous membrane of the middle ear, when there are granulations in the external and middle ears, in marked desquamation of the external meatus, and in caries of the tympanic walls and ossicles.*

Of the powdered medicaments, iodoform is still used at times. Its general use is, however, limited on account of its intense odour, and for the reason that some patients have a marked idiosyncrasy against it. Powdered iodol (Stetter), which belongs to the same class as iodoform and is odourless, is not as efficacious as the latter, but is, nevertheless, serviceable in some cases, especially in scrofulous, tubercular, and syphilitic suppurations.

The author did not see any special value in use of bichloride of mercury (0·05:50·0), benzoic acid, aristol, xeroform, and dermatol in the treatment of chronic middle-ear suppurations. E. Urbantschitsch (*Monat. f. Ohrenheilk.*, vol. xxxvii.) reports favourable results with thigenol in aqueous (2·0 glycerin., aqua. dest., āā 10·0) or alcoholic solutions (5·0 spirit. vini rect., aqua. dest., āā 10·0).

2. **Alcoholic Treatment.**—Alcohol has proved to be the best remedy in chronic uncomplicated middle-ear suppurations. As the concentrated form often produces severe burning in the beginning, it is advisable to dilute it with two-thirds or an equal amount of distilled water, and gradually to increase its strength. The fluid, which is first warmed, is allowed to remain in the ear from ten to fifteen minutes, and removed only if severe burning or pain is experienced. The pain may also be lessened if we first introduce 2–3 drops, and the rest of the fluid (30 drops) half to one minute later. In the majority of cases alcohol is not used in the pure state, but is generally combined with boracic acid or hydrogen peroxide. A good mixture consists of acid. boric. $\frac{1}{3}$, spir. vini rect. and hydrogen peroxide āā ʒi. Ten drops to be used 4–5 times a day, and allowed to remain in the ear for 5–10 minutes. The use of alcohol should, as a rule, be limited to chronic cases only. It may also be combined with other drugs, as carbolic acid, bichloride, iodol, etc., in varying strengths.

The mucous membrane of the promontory wall, which is deep-red, presents, immediately after the use of alcohol, a pale-gray, reddish colour, due to the coagulation of the mucus and albumen on its surface. The beneficial effect of alcohol is often seen, even after its application for several days, by a diminution in the discharge.

3. **Caustic Treatment.**—The caustic treatment, which is used in only a small group of chronic middle-ear suppurations, consists in the instillation of a few drops of a warm solution of nitrate of silver (0·3–1·0:10·0–15·0 aqu. dest.) into the meatus. If the ear is first thoroughly cleansed, we find that the drug has a cauterizing action upon the swollen secreting mucous membrane of the

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* Cp. F. Köbel, *Ueber kritiklose Pulverbehandlung bei Mittelohreiterungen.* *Med. Korr.-Bl.*, 1890.

middle ear. In addition to this, silver nitrate solutions also possess marked antiseptic properties, and do not cause much pain. Where the mucous membrane of the middle ear is sensitive, it can first be anæsthetized by the instillation· of a 3 to 5 per cent. cocaine solution (which must again be wiped out) before introducing the silver solution.

The formation of an eschar takes place rapidly. The excess solution must be removed after two to three minutes by thoroughly syringing the ear. Neutralizing the silver nitrate by syringing the ear with a normal saline solution is not advisable, inasmuch as the precipitates of chloride of silver adhere firmly to the mucous membrane. The appearance of brown spots on the external region of the ear may be prevented by painting the parts with a solution of potassium iodide. The eschar usually falls off within twenty-four hours, but sometimes remains for two to three days. As a rule, cauterization should not be repeated until the scab has been cast off.

The caustic treatment proves most effectual in large defects of the membrane, and in simple non-granulating swelling of the middle-ear mucous membrane. This method of treatment is contra-indicated in small perforations which prevent the discharge of the insoluble albuminate of silver from the tympanic cavity, in extensive granulations in the middle ear, in the desquamative processes, in caries of the temporal bone, and when there is fœtid secretion.

The action of the caustic often becomes manifest after two or three applications by a diminution or complete cessation of the suppuration. Frequently, however, silver nitrate is ineffectual even after its application for several weeks, and a rapid diminution in the suppuration in such cases is observed only when we have recourse to the use of boracic acid, alcohol, or Burow's solution. According to Okunef, cauterization with trichloraeetic acid is superior to that with silver nitrate.

Astringents.—The astringent solutions which were so frequently employed in the treatment of chronic middle-ear suppurations are the following: Zinc. sulph. (0 2–0·4 : 20·0), sacch. saturn. (0·2–0·4 : 20·0), cupr. sulphur. (0·1 : 20·0), alum. crud. (0·3 : 20·0), acet. zinci (0·2 : 20·0), and liquor Burowii (1 : 3) These are, however, hardly ever used, as they have no advantage over the antiseptic treatment. Burow's solution has proved most beneficial when the antiseptic and caustic treatments have proved ineffectual.*

Washing out the Tympanic Cavity.—Washing out the tympanic cavity with warm water *per tubam* (*vide* p. 124) has proved a valuable method in the treatment of obstinate middle-ear suppurations. A normal saline solution is most serviceable for this purpose. This method of washing out the tympanic

* Cp. E. B. Dench, 'Treatment of Chronic Suppuration of the Middle Ear' (*New York Medical Journal*, May 4, 1907). A. C. Heath, 'Conservative Treatment of Suppurative Otitis Media' (*St. Paul's Medical Journal*, March, 1907). Seymour Oppenheimer, 'The Importance of the Treatment of Chronic Otorrhœa' (*New York Medical Record*, vol. lxx.)

cavity is especially beneficial in those cases in which there is a profuse mucous discharge, and in cases in which there are accumulations of thickened, cheesy masses in the tympanic cavity. The author has seen a striking improvement in the discharge result from the use of this method in the complicated middle-ear suppurations in which the excessively developed mucous mem brane of the middle ear extended through the perforation into the external meatus, and also in those cases in which the secondary swellings and strictures of the external auditory canal prevented the introduction of drugs in the ordinary way. If pain and dizziness arise because the injected fluid cannot escape from the meatus, only moderate, gradually increasing pressure should be employed. Where washing out the tympanum *per tubam* cannot be carried out, we may first try the method proposed by the author of washing out the middle ear from the external meatus (*vide* p. 138). This method is of less value, because the fluid injected into the external meatus has little effect upon the contents of the attic. This procedure should be used only when the fluid flows off easily through the Eustachian tube into the pharynx without causing dizziness. The author has seen a rapid diminution and cessation of an obstinate discharge follow the repeated application of this method, and is of the opinion that here, as well as when washing out the ear through the catheter, the beneficial effect is most pronounced on the mucous membrane of the tube, which, through its continuity with the mucous membrane of the tympanic cavity, exercises a favourable influence upon the swelling of the latter.

The Dry Treatment of Chronic Middle-Ear Suppuration.

The dry treatment of introducing gauze strips or cotton firmly into the middle ear without irrigations or the use of drugs has proved effectual in chronic middle-ear suppuration in which there is a slight non-fœtid secretion, and in simple swelling of the mucous membrane of the tympanic cavity. In these cases a recession of the cell-growth and a diminution in the swelling of the mucous membrane of the promontory are brought about by the pressure of the gauze or sterilizd cotton upon the swollen mucous membrane. Through continuity, this beneficial effect is distributed to all parts of the accessory cavities of the middle ear. On the other hand, the dry treatment is decidedly disadvantageous when the discharge is copious, fœtid, and curdy, and in all middle-ear processes which have a tendency towards desquamation. Where, therefore, the discharge is foul-smelling and curdy, syringing the ear is indispensable and the better method of treatment. This is all the more important, as it has been shown that, by the removal of the secretion in the external meatus, sepsis in the middle ear is prevented. A

thorough cleansing of the external meatus by the dry treatment is absolutely impossible.

This method of treatment is therefore indicated only when there is a mild non-fœtid secretion, which is aggravated by syringing, and when severe dizziness is produced even with weak injections. On the other hand, it is contra-indicated when there is a profuse septic secretion, in the desquamative processes, when there are polypi in the cavum tympani, in caries· of the temporal bone, and when there is great irritability of the lining membrane of the external meatus and of the mucous membrane of the middle ear. ·

The method of carrying out the dry treatment is as follows: An inflation of air is first given, whereby the secretion is driven into the external meatus, which is then wiped out as thoroughly . as possible with small cotton pledgets. A long tampon of sterilized absorbent cotton or a strip of sterilized gauze is then introduced with forceps as far as the perforated membrane, or even .into the tympanic cavity. Gauze impregnated with different medicaments is now frequently used (salicylic, boracic acid, bismuth, xeroform, dermatol, airol, bichloride of mercury, aristol, etc.); by means of this gauze the secretion is not only absorbed, but the impregnated drug is supposed to exercise a beneficial effect. The gauze is changed several times a day according to the amount of discharge. If the secretion is scanty, once every 3–4 hours is sufficient.

The Treatment of Granular Suppuration of the Middle Ear.

In the course of chronic middle-ear suppuration, round or nipple-like excrescences develop on the mucous membrane of the middle ear, and on the remnant of the membrana tympani (*vide* p. 381); these impart a granular appearance to the drum membrane and wall of the promontory, and are distributed over a greater portion of the mucosa, or limited to single groups on the inner tympanic wall (*vide* p. 387, Figs. 181 and 182).* It is important to recognize these granulations, as the purulent discharge will not cease until they have been removed.

Granular middle-ear suppuration proves very obstinate to the methods of treatment already described. It is only by the long-continued use of alcohol that we are often able to bring about a disappearance of the granulations and a cessation of the suppuration. A rapid result can, however, be obtained by the operative removal of these granulations.

Cauterization of the growths is indicated if they are located on the remnant of the tympanic membrane, on the attic wall, or on the accessible visible parts of the inferior or posterior walls

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* The author has also found microscopically small papillary formations on the lining membrane of the mastoid antrum, and in the mastoid cells.

of the tympanum. On the other hand, however, cauterization of the promontory wall must be avoided under all conditions, because, if there is a diseased condition of the bone, a labyrinthine suppuration may be brought about which might result in a serious complication.

The author has found the liq. ferri muriat. s. sesquichlorat. the most efficient caustic, because, after two or three applications, the granulations usually disappear. The cauterizing medicament is applied by means of a probe, or with a very small cotton applicator. The cauterization is seldom painful, especially if the granulations have first been anæsthetized with powdered cocaine. Cauterization should be repeated only when the eschar has fallen off. A 10 per cent. or even stronger solution of trichloracetic acid is one of the most serviceable cauterizing agents. As its application produces severe pain, it is advisable first to apply powdered cocaine. The application is carried out with a small, thin cotton tampon attached to the end of a probe. Chromic acid is too violent and very painful.

Destruction of the granulations with the galvano-cautery is, as a rule, preferable to treatment with caustics. It possesses the advantages that the pain is only momentary, that the growths are more thoroughly destroyed, and that the reaction is less severe.*

The author found that one thorough cauterization of the granulating mucous membrane by this method is often sufficient to bring about a shrivelling up of diffuse growths which cannot be affected with caustics.

Fig. 224.

The operative removal of granulations from the tympanic cavity is carried out by means of small, sharp spoons. The author uses a series of small, sharp, steel spoons, which are either straight or bent in different directions, and which can be fastened in a handle in various positions by means of a screw (Fig. 224). With the aid of these, granulations in the external meatus, tympanic cavity, and Prussak's space can be removed without any difficulty. The removal of these growths with the spoon is rendered almost painless if we first cocainize the parts. Special care must be taken in removing granulations from the promontory wall, inasmuch as the periosteal layer of the mucous membrane and the bone itself may be injured by using too much force. A few granulations which still adhere to the mucous membrane after the operation come away

* Cozzolino, *La Galvano-caustica nelle malattie dell' orecchio. Medicina Contemporanea*, Napoli, 1884.
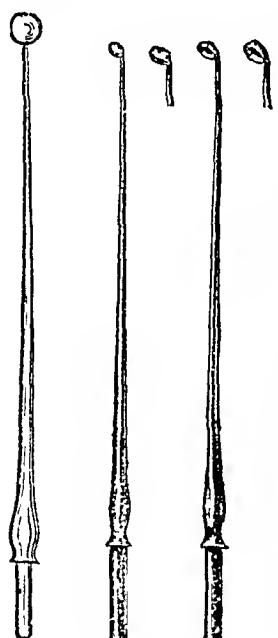
spontaneously. Growths which still remain can be made to shrink by instillations of alcohol. We are often able, in addition to removing the granulations, to scrape away superficial carious parts of the bone, and thus to bring about a cure more rapidly.

The Treatment of Middle-Ear Suppuration with Perforation of Shrapnell's Membrane.

The obstinate suppurations running their course with perforation of Shrapnell's membrane, and localized in the external attic, are caused partly by the anatomical structure of the external attic which is conducive in bringing about a retention of the secretion, and partly by caries of the malleo-incudal body and margo tympanicus. This last-mentioned condition can sometimes be recognized with the aid of a probe.

Where, in suppurations associated with perforation of Shrapnell's membrane, no caries is found in the region of the defect, we first confine ourselves to the antiseptic treatment, which, if conscientiously carried out, often brings about a cessation of the discharge after several months. As the secretion often has a foul odour, the attic must be syringed out daily with an antiseptic solution by means of a Hartmann or an elastic cannula, which is introduced into the attic through the perforated Shrapnell's membrane. For this purpose the Hartmann cannula, made of metal or hard rubber (Fig. 225), is most serviceable, the size of which varies according to the size of the perforation in Shrapnell's membrane and in the external attic wall. The injection is made with a glass syringe which is connected to the cannula by a rubber tube. In order to avoid the pain caused by the introduction of the cannula into the perforation, it is advisable first to place a pledget of cotton soaked in a 3 or 5 per cent. solution of cocaine against the perforation, and to allow it to remain there for a few minutes.

Fig. 225.—HARTMANN'S CANNULA. HALF-SIZE.

For irrigation one may use any cleansing solution. After the attic has been washed out, the fluid, which is still retained, is blown out by air through the same cannula. A few lukewarm drops (10–15) of an alcoholic solution of boracic acid, iodol (1 : 20), or bichloride of mercury (0·02 : 20) are next injected into the cavity without removing the cannula. In several cases of attic suppuration the author has found balsam of Peru most advantageous, which is introduced into the perforation by means of a small applicator. Sometimes insufflations of finely-powdered boracic acid into Prussak's space, by means of a delicate cannula or by means of the very practical powder-blower

devised by the author, have a beneficial effect upon the suppura-
tion.　Repeated instillations of peroxide are also very beneficial
in this form of suppuration.

The treatment of the desquamative processes consists mainly
in the removal of the epidermal masses known as cholesteatomata
from the middle ear.　The method of removing such masses
depends on their location, and varies according to whether they
have accumulated in the inferior or superior part of the tympanic
cavity, in Prussak's space, or in the mastoid process.　The
method of procedure is furthermore influenced by the condition
of the opening in the membrane—that is, whether it is large or
small, and whether or not the external meatus is narrowed.

Where the external meatus has retained its normal dimen-
sions, and the defect in the membrane is sufficiently large, it is
often possible to wash out cholesteatomatous masses from the
inferior and middle tympanic spaces by forcibly syringing the
ear, having first loosened them with a blunt probe.　A delicate
drainage-tube attached to the end of the syringe, and pushed
into the deeper parts of the meatus, facilitates the removal of
the masses.

If the meatus is narrowed, and even forcible syringing proves
ineffectual, the removal of the masses from the inner parts can
be brought about by the introduction of an elastic tympanic
catheter (Fig. 226) through the stricture into the deeper parts,

FIG. 226.

through which the fluid is injected.　A permanent cure can,
however, be obtained in the majority of cases of this nature only
by operative measures.

In cases in which the accumulated masses of epidermis in the
tympanic cavity cannot be removed on account of the small size
of the perforation in the drum, the author uses with advantage
the elastic tympanic catheter, which is introduced into the
tympanic cavity *after* having previously anæsthetized the parts
with a 5 per cent. cocaine solution.　The solution is now injected
through this catheter, by which means the masses are generally
washed out.　If the intratympanal injections prove insufficient,
it is advisable to enlarge the opening in the membrane, whereupon
the tympanic cavity can be washed out with ease.

It is much more difficult to remove masses which have accu-
mulated in the attic of the tympanic cavity and in the mastoid
antrum.　In such cases, even if the perforation is large, we are
hardly ever in a position to remove large parts of the chole-
steatomata by powerful injections into the external meatus.　By

introducing the above-described Hartmann cannula, however, behind the upper border of the perforation in the drum, we are usually able to wash out the stagnated secretion and cholesteatomatous masses from the attic.

In many cases of this nature, associated with large perforations of the drum, the author found that in spite of forcible injections, large pieces of cholesteatoma remained in the concavity of the external attic wall. In order to remove these, he uses a series of small spoons which are bent at a right angle at the end, so that they can be readily introduced into the upper tympanic space.

If with large accumulations of cholesteatoma in the middle ear, or with marked stricture of the external meatus, injections prove ineffectual, it is advisable to resort to the method of washing out the middle ear *per tubam* with a warm saline solution, as already described on p. 123. The thickened masses in the tympanic cavity are thus dissolved, and a portion is often expelled through the perforation into the external meatus. It is advisable to perform the injections through the catheter slowly, in order to avoid the unpleasant sequelæ of a sudden increased pressure in the labyrinth. Washing out the middle ear *per tubam*, combined with syringing from the external meatus, can sometimes be used to great advantage.

The effect of these irrigations *per tubam* is often surprising, as not only the pain in the ear and the troublesome pressure in the head are immediately alleviated after removal of the cholesteatomatous masses from the middle ear, but the annoying symptoms, as dizziness and stupefaction, also disappear.

Having thoroughly removed the epidermic masses, it is advisable to give the patient instillations of peroxide several times a day, whereby the small epidermic masses which have been left in the deeper parts are brought to the surface. Even when the cholesteatoma has been thoroughly removed from the middle ear, and the otorrhœa has ceased, we must again resort to instillations of peroxide, followed by irrigations of a weak saline solution, at intervals of eight to fourteen days, in order to prevent relapses.

The cholesteatomatous accumulations in Prussak's space, and in the external portion of the attic of the tympanic cavity, must be removed by a special method of procedure. The cholesteatomata which always develop here through invasion often reach the size of a pea, and at times produce severe pain, dizziness, and inflammatory swelling in the external meatus. Simple injections from the external auditory canal, and washing out the middle ear *per tubam*, almost always prove ineffectual in such cases. On the other hand, it is often possible to force the accumulated masses into the external meatus by introducing a Hartmann cannula through the perforated Shrapnell's mem-

brane. In order that all portions of the external attic may be reached by the fluid, we must alternately direct the cannula forwards, upwards, and backwards. Attacks of dizziness which arise during this manipulation are quickly alleviated by rarefying the air in the external meatus.

Small perforations in Shrapnell's membrane, which prevent the discharge of the cholesteatomatous masses, must be enlarged by incisions in different directions. If it is not possible to force the cholesteatomatous masses out of the attic by injections with the cannula, we must resort to curettes or to various-sized sharp spoons bent at right angles to their long axes (Fig. 224); these instruments may also be employed for the removal of small polypi and granulations from this cavity, and for scraping away carious or softened margins of the margo tympanicus.

By this conservative treatment it is possible, in a limited number of cases, to arrest the suppuration running its course with the formation of cholesteatomata for a considerable length of time. As in the majority of cases there is an anatomical predisposition to recurrences, such patients must be examined for years by the physician at intervals of three to four months, so that newly accumulated masses in the deeper parts can be timely removed. If the patients are allowed to syringe their ears once or twice a week with a weak, lukewarm, sterilized, boracic acid solution, or salt water (having first used instillations of diluted glycerine to soften up the masses), and then ordered to instil peroxide into the canal, relapses can be prevented in the majority of cases. This conservative treatment has yielded very satisfactory results in many of the author's patients, who have been under his observation for a number of years.

The operative exposure of the attic by the removal of its external wall offers the best results. As, however, the cholesteatoma in the attic is often in direct communication with one in the mastoid antrum, cure is seldom attained by the simple removal of the external attic wall alone; so that in the majority of cases the antrum must also be laid bare (Stacke), or we must eventually resort to the radical mastoid operation (see chapter on The Radical Mastoid Operation, p. 518). Patients as a rule, however, subject themselves to these operative measures only when threatening symptoms appear. When these are lacking, and if the hearing is not greatly affected, the patients prefer the conservative treatment, which may continue for years.

If no cure is obtained after treatment for several months, and if the foul-smelling discharge continues in spite of energetic antisepsis, we proceed—presuming that there are no indications for a radical mastoid operation—to the extraction of the malleus and incus (p. 486), and eventually even to exposure of the external attic by the removal of as much of the margo tympanicus as

possible. That this latter operation is indicated in such forms of suppuration is shown by the fact that a spontaneous cessation of the purulent discharge at this place is observed after the formation of extensive defects in the attic through carious destruction of the margo tympanicus.

The opening up of the external attic can be carried out by different methods. The usual procedure consists in removing with small sharp spoons (*vide* p. 434) that part of the margo tympanicus which borders on the perforation of Shrapnell's membrane, and is usually of a soft carious nature. The operation can be performed under periosteal local anæsthesia, as proposed by Neumann, and in exceptional cases under a general anæsthesia. While performing the operation we must take care that the instrument is not pushed inwards during the manipulation, as we may easily dislocate the malleo-incudal body. Owing to inflammatory softening of the bone, the removal of the bony margin is *more easily accomplished in the neighbourhood of* Shrapnell's membrane than higher up. The hæmorrhage which ensues during the operation is usually very slight, owing to the injection of adrenalin, and can be readily arrested by gently packing with gauze. After the operation the meatus is filled with peroxide, which is allowed to remain for five to ten minutes, after which the cavity formed by the operation is packed with a strip of sterile gauze.

Chiselling away the external attic wall through the external meatus without detaching the auricle has been carried out in the last few years with gratifying results by the author and by Neumann. Having first performed periosteal anæsthesia (see Extraction of the Ossicles), a small piece of the skin with the periosteum is cut away, exposing the bone, whereupon small pieces of the external attic wall are chiselled away by means of small gouges 4–6 mm. in width, which are bent at an angle or fastened to a small handle; this procedure is begun above the perforated Shrapnell's membrane. The operator directs the chisel, keeping the field of operation always in view, while an assistant gently hits upon the chisel with a small hammer. In this way as much of the attic wall is removed as desired until a large free opening is obtained. It has been found advantageous, however, to push a small ball of cotton into the external attic as a protection to the ossicles.

If a sufficiently large opening has been made in the external attic wall, the loosened fragments of bone are removed with a pair of aural forceps; the wound cavity is then cleansed with peroxide and packed with a narrow strip of sterile gauze. The dressing must be changed every day. The pain which arises after the operation is most readily alleviated by the internal administration of pyramidon (0·3 per dose), or some mild narcotic. The suppuration which follows the operation usually lasts ten to

fourteen days, during which time the borders of the cavity become covered with granulations, which in turn are covered with epidermis in the course of a few weeks. In cases in which the attic suppuration is cured, the epidermis of the external meatus sometimes grows through the artificial bony opening into the attic, and leads sooner or later to the formation of cholesteatoma in the antrum and mastoid process. Such patients must, therefore, always remain under the supervision of the physician, who must from time to time remove the invading epidermis from the attic and antrum by means of suitable cannulæ.

Crusts which adhere firmly to the membrana tympani or to the walls of the tympanic cavity are softened by the introduction of a small ball of sterilized cotton saturated with dilute glycerine; after twenty-four hours these can be removed with a probe or forceps, or can be syringed out with sterilized warm water. If the latter method is employed, the water must be thoroughly removed from the ear by the introduction of small cotton plugs, or by forcible inflations of air in the external meatus, in order to prevent a relapse of the middle-ear suppuration.

Concluding Remarks in Reference to the Treatment of Chronic Middle-Ear Suppuration.

It can be seen from the foregoing that a free discharge and a thorough removal of the stagnant secretion from the middle ear are the most important factors in the local treatment of chronic middle-ear suppuration. Drugs which prove effectual in some patients are of no value in other patients. One is therefore often compelled to change the drugs until one finds the one having the best effect. The result of this alternating treatment is often surprisingly rapid. Occasionally the suppuration ceases only when the use of drugs is entirely suspended, and when we confine ourselves to inflations of air after the author's method, and to simple syringing. It also happens that spontaneous cure not infrequently takes place without any local treatment.

It must be stated that, as a general rule, the treatment of chronic middle-ear suppuration must not be interrupted for any length of time as long as the discharge continues if we wish to prevent the dangerous sequelæ of a neglected otorrhœa. When the patients are not in the position to visit the physician regularly, it is most urgent to instruct them or their relatives in the necessary manipulations of syringing and of applying the medicaments. They must also be warned to observe strict antisepsis, as only by this means can any result be obtained. In every case, however, the result of self-treatment must be watched by an occasional examination of the patient.

The time in which chronic middle-ear suppuration can heal by local treatment depends on the anatomical changes in the

middle ear, on the amount of sepsis, and on the cause of the affection. Accordingly, we often see a middle-ear suppuration which has lasted a long time come to an end after a short treatment;* while, on the other hand, a result is often obtained only after several months, or, after all local treatment has proved of no avail, we are compelled to resort to the operative opening of the middle-ear spaces.

The local treatment of chronic middle-ear suppuration often exercises a favourable influence upon the general system. Anæmic, emaciated children often attain a healthy, flourishing appearance after cessation of the discharge. The development of certain general diseases may be prevented by the cessation of such a suppuration; this is shown by the fact that symptoms of scrofula and tuberculosis sometimes arise during the course of chronic otorrhœa, and that miliary tuberculosis may develop from the temporal bone through destruction and absorption of the caseated pus (v. Tröltsch).† just as from a caseous ostitis of other bones.

In prescribing an internal treatment for chronic middle-ear suppuration,-we must take special notice of the general disease existing at the time. Anæmia, scrofula, and syphilis are those particular affections in which local treatment must always be combined with a proper general treatment. As the same rules apply here as in the middle-ear catarrhs, we refer the reader to that chapter (p. 285).‡ The treatment of naso-pharyngeal catarrhs accompanying chronic middle-ear suppurations require careful attention.

After the suppuration has ceased, all local medication must be suspended, for experience has shown that the discharge may easily recur by syringing or by the use of instillations, as well as by any procedure which would cause an irritation to the mucous membrane. As relapses not infrequently arise after an exhausted, uncomplicated middle-ear suppuration, the author orders the patient to instil every eight to fourteen days a few drops of warm peroxide or warm alcohol in progressive strengths. In a few cases of adhesive connective-tissue formation in the middle ear, the author has also observed a striking improvement in the hearing, seldom a change for the worse, follow the use of instillations of alcohol for several weeks.

In cases in which the perforation remains persistent after the suppuration has run its course we must try to prevent relapses;

* Faust, Brunetti. *Otite med. purulent. cron. che datava de 35 anni guarita in un mese. Rivista veneta di scienze mediche.* tom. iii., fasc. v.

† Th. Barr. *Caseous Accumulations in the Middle Ear as a Probable Cause of Miliary Tuberculosis. Transact. of the Intern. Med. Congress. London.* 1881.

‡ Cp. Hessler, *Der Einflus des Klimas und der Witterung auf die Entstehung, Verhütung und Heilung von Ohr-, Nasen- und Rachenkrankheiten. Haug's Klin. Vorträge.* ii. 7. 1897.

this is best accomplished by protecting the ear from external harmful influences, as the action of cold, wind, moisture, and dust upon the exposed mucous membrane of the middle ear may again bring on the suppuration.   To do this, the external auditory orifice should be protected with a small piece of cotton, and the patient must be instructed to avoid the entrance of fluid into the external meatus while cleansing the ear or while bathing, as often a relapse may be brought about by the entrance of a few drops of water.

The Treatment of the Disturbances of Hearing in Chronic Middle-Ear Suppuration.

(a) In the treatment of the majority of cases of disturbance of hearing brought about by chronic middle-ear suppuration, better results are obtained by inflations of air after the author's method than by catheterization of the tube.   The degree of improvement in the hearing depends on the nature of the changes in the middle ear.   If the inflations of air are continued too long, they have a harmful influence upon the hearing; it is therefore advisable to give them only two to three times a week, and after four to five weeks' application to stop treatment for two to three weeks. The inflations should be continued at short intervals only in those cases in which the discharge is copious, and in which we wish to prevent its stagnation.

Rarefaction of the air in the external meatus (p. 135), by which the pus, which is localized in the tympanic cavity, can be aspirated into the external canal, may also be used with advantage for the disturbances of hearing arising after an exhausted middle-ear suppuration.   A striking improvement in the hearing, which is generally only temporary, is especially noticeable after the alternating rarefaction and condensation of the air in the external meatus (massage).   This procedure is indicated in adhesions between the membrane and inner tympanic wall; in adhesions of the membrane with the incudo-stapedial articulation, or with the stapes which has been separated from the incus; in those cases in which the posterior part of the tympanic cavity is separated from its anterior portion by cicatricial formations; and in all conditions in which inflations per tubam have proved ineffectual.

(b) **The Artificial Drum Membrane.**—In a paper by Marcus Banzer (Disputatio de auditione læsa, 1640) references are already made to the use of an artificial membrane; we then find that Autenrieth (Tübinger. Bel. f. Nat. u. Arzneik, vol. i., 1815), Itard, Deleau, Tod, and Lincke (vol. ii., 1845) also wrote on the same subject.   It was not until 1848 that Yearsley, and in 1849 Erhard, proposed independently of each other that in those cases in which there was a perforation of the membrane the hearing could be improved by placing a ball of cotton against the remnant of the membrane.   Shortly after, Toynbee (1852) published the favourable results which he obtained with his artificial drum membrane.

The artificial drum has proved an indispensable help in aural practice, if we consider the large number of aural patients in whom no decided improvement in their disturbance of hearing is obtained by the ordinary methods of treatment, and in whom the hearing is often so strikingly improved by the application of the artificial membrane that they are again able to enter into undisturbed intercourse with those about them after a deafness of many years' standing (H. N. Spencer, *St. Louis Polyclinic*, 1889).

Toynbee's artificial drum membrane (Fig. 227) consists of a round rubber plate 6–7 mm. in diameter; this is fixed to the end of a silver wire which corresponds in length to the meatus. Lucae uses a thin, small rubber tube, and Burckhardt-Merian a solid rubber strip, instead of the metal wire.

Toynbee's membrane often becomes useless even after several weeks' application; the author, therefore, devised for the use of poor patients an artificial membrane, which is easily and simply made. For this purpose we take a rubber tube 2–3 mm. in thickness, from the wall of which a piece is cut away 1 cm. long, into which a moderately strong wire is inserted (Fig. 228). In some cases in which attempts with other artificial membranes were without result, the author has observed a striking improvement in the hearing follow the introduction of this rubber tube.

FIG. 227.—TOYNBEE'S FIG. 228.—ARTIFICIAL FIG. 229.—HASSENSTEIN'S
MEMBRANA TYMPANI. [MEMBRANA TYMPANI COTTON-WOOL CARRIER.
    FOR USE IN PRACTICE
    AMONG THE POOR.

Hassenstein's cotton carrier (Fig. 229) consists of a small metal forceps, 3½ cm. long, by which a firmly rolled, long piece of cotton can be held. The branches of this small instrument can be approximated so closely by a small movable ring that the piece of cotton cannot fall off.

A. Hartmann uses an artificial membrane which is made of a piece of whalebone 5 cm. long and 2 mm. wide. The one end of the bone which is covered with cotton is then bent back 1 cm., and united with the remaining part of the whalebone by means of the cotton.

The cotton carriers devised by Ch. Delstanche are very practical and simple; they consist of a cotton pencil or ball, which is twisted upon a thin metal wire.

Gomperz recommends using silver leaf, which is chemically pure, instead of the cotton pledgets, as its non-irritative property permits it to remain in the ear for months. He also uses drums made of a mixture of vaseline and paraffin

The artificial drum is used mainly in deafness following an exhausted middle-ear suppuration, less often during the course

of the affection. The choice of the artificial membrane always depends on its action in each particular case. In every case, therefore, in which such an appliance is necessary we must try different forms, and we must select that one which proves most effectual in that given case. In the last few years the author has used small balls of cotton in the majority of cases. These cause the least irritation, possess the advantage of absorbing the secretion if still present, and also have a medicinal action upon the diseased mucous membrane of the middle ear, if the cotton has been impregnated with boracic or with some other antiseptic powder. In cases of exhausted middle-ear suppuration, the small cotton balls dipped into sterilized liquid vaseline (Blake) or in a mixture of the oleate of zinc vasogen (0·3) and liquid vaseline (15·0) are borne the best. At times a dry ball of cotton which can be introduced with a pair of forceps, or boracic acid which is insufflated in thin layers, acts like an artificial drum.

The author now uses Toynbee's membrane only in such cases in which it is more effectual than the other modifications. It often causes a troublesome crackling in the ear while conversing or eating, which is not experienced when a small ball of cotton, Hassenstein's or Delstanche's instrument is employed.

The introduction of the artificial membrane is best accomplished by the patient himself, after he has been instructed by the physician. As the effect of the instrument depends principally on its position, and on very slight variations of pressure, it will be found that the patient will strike the correct spot through practice with much more certainty than the physician himself. If no improvement in the hearing is noticed at the first insertion, we must nevertheless try again, as often after several fruitless attempts a striking effect is obtained.

The artificial membrane is indicated in large, seldom in small, perforations of the membrane, in those cases in which a hearing power sufficient for ordinary intercourse cannot be attained by the ordinary local treatment. The artificial membrane is contra-indicated if it increases the purulent discharge, and if it again sets up an otorrhœa after an exhausted middle-ear suppuration.

The degree of improvement in the hearing after the introduction of the artificial membrane depends on the anatomical changes in the middle ear. The increase is often so marked that patients who could understand only when spoken to in the immediate vicinity are able to hear speech at 6–8 metres and over. In other cases the increase is only $\frac{1}{2}$ or $\frac{1}{3}$ metre. Even this result is a great gain to many patients, inasmuch as they can continue at their occupations. In several cases of total deafness, the author has seen such improvement follow the introduction of an artificial membrane that patients were now able to hear quite well sentences spoken into the ear.

The improvement in hearing obtained by the use of the artificial membrane usually disappears after the removal of the instrument; not infrequently, however, this improvement remains for a short time. On the other hand, cases are occasionally met with in which a permanent improvement takes place after the membrane has been worn for several days, and it is advisable, under such conditions, to gradually get the patients accustomed to do without this aid. When the artificial membrane has been used for some time, it is advisable to suspend its application from time to time for several days, as it has been found that its effect is more favourable after such a pause than when it is used uninterruptedly.

The artificial membrane, like any foreign body, causes an irritation to the remnant of the membrana tympani, and to the mucous membrane of the tympanic cavity. The affected parts must therefore gradually become accustomed to the contact of the instrument. The author allows the artificial membrane to be worn half an hour during the first four or five days, and always increases its use by half an hour every fourth or fifth day. Its daily application should never exceed six to eight hours. As a rule, the patient should use it only in the company of others, and again remove it when alone. The instrument must always be removed before retiring, and the ball of cotton must be changed every day. If secretion is present, the ear must be cleansed before the introduction and after the removal of the artificial membrane, and some boracic acid must occasionally be insufflated, or one of the before-mentioned medicated lotions instilled. It must finally be mentioned that the observations of v. Tröltsch, Ménière, Pomeroy, the author, and others, have demonstrated that in cases of non-perforation a considerable improvement in the hearing may sometimes be obtained by pressure of the cotton tampon upon the membrana tympani.

Intratympanic Operations in Chronic Suppuration of the Middle Ear.

A. Operative Procedures during Suppuration.

1. Enlargement of Small Perforations.—This is indicated:

(*a*) In cases of thick mucous secretion, when the escape of the mucous masses through the narrow opening is prevented, and when symptoms of stagnation are present. The enlargement of the opening induces a more rapid outflow of the pus, heightens the effect of the air-douche, and facilitates the syringing of the tympanic cavity through the tube. The result is sometimes transient, as the incision often recloses rapidly.

(*b*) In cases of small perforation, when violent reactive symptoms

appear in consequence of pus retention due to the occasional agglutination of the edges of the wound, or to occlusion of the opening in the membrana tympani by inspissated secretion.

(c) When there is an accumulation of cholesteatoma in the middle ear, which occludes the perforation, causing a bulging of the membrana tympani, and giving rise to dangerous complications (*vide* p. 421). By enlargement of the perforation the obstacle preventing escape of the hardened secretion into the auditory canal is not only removed, but the introduction of a small cannula through the perforation into the tympanic cavity, necessary for the liquefaction and removal of the secretion, is rendered possible.

(d) When there are polypi and granulations in the tympanic cavity, which bulge the membrana tympani outwards and prevent the escape of pus. In these cases, enlargement of the perforation permits one to introduce into the tympanum the instruments necessary for the removal of these new formations.

(e) In cases of obstinate suppuration of the middle ear in which the small size of the perforation does not allow the introduction of the tympanic catheter or cannula for washing out the tympanic cavity.

The operation consists in the introduction of a paracentesis knife through the perforation, and enlarging it by an incision 3–4 mm. long. The incision must always be made in that part of the membrane which is seen to bulge the most. Immediately after the operation thick pus, cheesy epidermic masses, or polypoid growths often escape into the meatus. A severe reaction seldom follows the incision. In those cases in which the edges of the wound unite quickly, it may be necessary to separate them again within a day or so.

2. **A Second Perforation in the Membrana Tympani is indicated** :

(a) In adhesions between the anterior segment of the membrana tympani and inner tympanic wall, when in the posterior tympanic space thus formed a purulent or mucous exudate gathers which is accompanied by the objective and subjective symptoms already described (p. 411).

(b) In perforations of the anterior segment of the drum, with a simultaneous marked bulging of its posterior part, when frequently recurring pains make it probable that there is a stagnation of pus, or an accumulation of caseous masses or polypoid growths in the posterior superior part of the tympanic cavity.

(c) In perforation of Shrapnell's membrane, if symptoms of pus retention in the lower tympanic space (called *atrium tympanicum*) are also present.

The formation of a second perforation not only affords a free outlet for the secretion, but allows the introduction of cannulæ and small tubes for the purpose of syringing out the secretion

and for injecting medicated solutions. A permanent cure is seldom obtained, however, by this conservative treatment, for the reason that the localized suppurations, which are generally limited to the posterior superior tympanic space, are, as a rule, very obstinate, and usually heal only after the operative opening up of the middle-ear spaces.

B. The Intratympanic Operations after Cessation of a Suppuration of the Middle Ear.

The intratympanic operations used to improve the disturbances of hearing which are due to the adhesive processes following a suppuration of the middle ear, give much better results than the intratympanic operative measures employed in the adhesive processes which arise from the non-suppurative diseases. The author thinks that this difference lies in the fact that in the non-suppurative forms of middle-ear affections the new connective tissue has a greater tendency to shrink than that formed from the granulations in the purulent processes, and that in the latter affections the labyrinth is less often involved than in the non-suppurative processes and in otosclerosis.

An intratympanic operation to improve the hearing after a suppuration of the middle ear has ceased, is indicated only if the deafness is marked, and if no increase in the hearing can be produced by the ordinary methods of treatment. Such an operative measure is furthermore indicated if the adhesive process is accompanied by intense subjective noises or by violent attacks of vertigo.

In order to determine the exact place where the adhesion should be severed, it is necessary to ascertain the degree of mobility of the ossicles and of the individual parts of the thickened or adherent membrane by means of Siegle's speculum. As a successful issue can be expected only when the auditory nerve is intact, one should decide on an operative procedure only in those cases in which the perception for a low-ticking watch through the cranial bones is preserved, and in which the duration of perception for a tuning-fork (Schwabach) placed upon the mastoid process is lengthened. An operation undertaken too soon after the cessation of the suppuration may easily bring about a relapse (Botey, Grunert).

The results of tympanic and intratympanic operations cannot be foretold. This is explained by the fact that, besides the visible changes, other complications, such as alterations in the membrane of the round window, may exist, which cannot be detected by the objective examination, and which render the success of an operative procedure impossible. Therefore, every surgical procedure should be regarded only as an experiment, and a successful issue should never be promised to the patient.

According to the author's experience, one may generally expect a good result from an intratympanic operation if the hearing is improved by massage, or by the introduction of a small ball of cotton soaked in vaseline.

The indications for operative treatment of the adhesive processes which have formed after a middle-ear suppuration has ceased are as follows:

(a) When a high degree of deafness exists in consequence of adhesions between the membrana tympani and inner wall of the tympanic cavity, and if on the surface of the membrane a network of projecting bands is seen, by which the ossicles are rendered immovable.

If examination with Siegle's speculum and with the probe proves that these projecting bands are tense, their incision is indicated. For this purpose the author employs a small, narrow knife (p. 322), rounded at the end, with which several small incisions are made down to the promontory wall at right angles to these bands. The results are especially good after incising cicatrices stretched between the retracted handle of the malleus and the articulation of the incus and stapes (Fig. 230), inasmuch as the rigid fixation of both these ossicles is removed. Although the edges of the incised adhesions again unite, the newly-formed cicatricial tissue seldom acquires the former degree of rigidity. In a number of cases a permanent improvement in hearing remains, while in the majority of cases it is only temporary, and the former degree of deafness returns.

(b) When the lower end of the manubrium is adherent to the wall of the promontory (Figs. 231 and 232), in which case the incus and stapes are pulled so strongly inwards that the greater part of their mobility is lost. The author has frequently observed that the hardness of hearing thus caused, which is often of a high degree, is considerably improved by repeated perpendicular incisions into the cicatricial tissue found in the immediate neighbourhood of the handle. When this procedure is without effect, an attempt should be made to sever the adhesion of the hammer to the promontory wall by means of a small curved knife (synechotome).

In order to prevent re-adhesion, Grunert[*] advises that after the hammer has been severed from its adhesions, and tenotomy of the tensor tympani has been performed, the manubrium should be drawn so far externally, by means of a small hook, that it retains its position several millimetres from the inner wall of the tympanic cavity. Gomperz[†] recommends the introduction of small celluloid plates, $\frac{2}{10}$ mm. thick, between the malleus and the promontory wall.

If, owing to adhesion of the malleus to the promontory wall, the articulation of the stapes and incus is visible behind the handle

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[*] *Arch. f. Ohrenheilk.*, vol. xliii.

[†] *Sitzungsber. d. österr. otolog. Gesellschaft*, 1899; and *Zur Therapie der Verwachsungen im Mittelohr. Wien. med. Wochenschr.*, 1900.

(Fig. 232), and circumcision of the cicatricial tissue around the adherent manubrium or its detachment from the inner wall of the tympanum is without effect, it is advisable to sever the long process of the incus in order to relieve the pressure on the stapes.

FIG. 230.—FORMATION OF BAND-LIKE CORDS BETWEEN THE LOWER END OF THE HANDLE OF THE HAMMER AND THE INCUDO-STAPEDIAL ARTICULATION. THESE BANDS WERE CUT AT RIGHT ANGLES, WHICH WAS FOLLOWED BY A MARKED IMPROVEMENT IN HEARING. IN A MAN AGED 48.
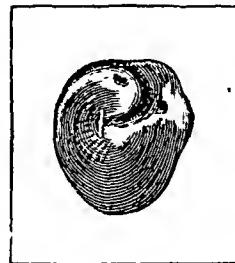
FIG. 231.—ADHESION OF THE LOWER END OF THE HANDLE OF THE HAMMER TO THE PROMONTORY.

(c) In thickening and rigidity of the posterior portion of the membrana tympani; when the posterior fold is very prominent, and is associated with retraction of the manubrium; in band-like thickenings of the non-adherent membrana tympani, and with
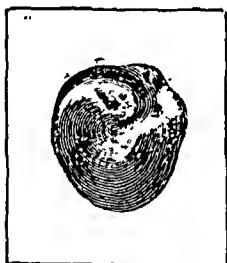
FIG. 232.—DIVISION OF THE LONG PROCESS OF THE INCUS.
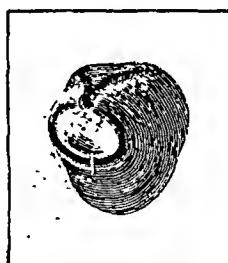
FIG. 233.—MOVABLE CICATRIX IN FRONT OF THE HANDLE OF THE MALLEUS. RIGID EDGE OF THE PERFORATION ADHERENT TO THE HANDLE OF THE MALLEUS. INCISION OF EDGE OF PERFORATION.

Before the operation: acoumeter = 10 cm., speech = 1 m. After the operation: acoumeter = 55 cm., speech = 4 m.

thickened edges of a perforation, through which the hammer is rigidly fixed (Fig. 233). In these cases the author has sometimes seen a permanent improvement in the hearing ensue when one or more incisions were made in the thickened tissue.

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(*d*) When there are new connective-tissue formations in the pelvis ovalis, by which the motion of the stapes is impeded. In extensive perforations of the drum membrane, the diagnosis of such synechia about the stapes is not difficult when the region of the fenestra vestibuli is plainly visible. The niche appears obliterated, and only the small head of the incus is more or less visible.

The operative procedure (synechotomy) consists in dividing the cicatricial tissue by a horizontal incision (Fig. 234) immediately beneath the capitulum of the stapes, whereby it becomes more movable. When only a very slight improvement follows this operation, the author makes another incision parallel to the first immediately above the head of the stapes, provided the long process of the incus is absent (Fig. 235).

FIG. 234.—SYNECHOTOMY OF THE CRURA OF THE STAPES.
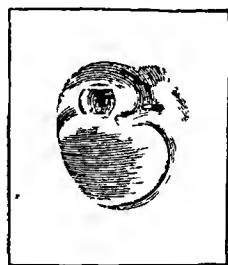
FIG. 235.—FIBROUS CONNECTIVE-TISSUE FORMATION IN THE REGION OF THE STAPES.

(*e*) **Intratympanic Operations on the Fenestra Cochleæ.**—In the last few years attention has also been directed to the niche of the fenestra cochleæ (fenestra rotunda), in order to ascertain whether the hearing could not be improved by intratympanic operations after exhausted middle-ear suppurations. Based on the histological examinations of the labyrinthine windows,* in which the author often found the niches of the windows filled with new-formed connective tissue, he became convinced that an improvement in the hearing could be obtained by the partial removal of this obstacle to the conduction of sound. In cases, therefore, of exhausted middle-ear suppuration with extensive destruction of the drum, in which the region of the fenestra cochleæ was visible, the author severed the cicatricial tissue with a small knife as shown in Fig. 236, *a*.

In some cases a marked improvement in the hearing and a diminution in the subjective noises were observed after this procedure, without even performing a simultaneous synechotomy of the stapes. In very few cases was the result permanent; in the majority of cases the improvement in hearing disappeared partially or entirely after several days or weeks. A repetition

* *Recherches histologiques dans les niches de la fenêtre ovale et la fenêtre ronde. Congrès de Bruxelles*, 1884.

of the division of the cicatricial tissue always brought about an increase in the hearing. In cases in which the niche of the window was favourably situated to the axis of the external meatus, a part of the connective tissue could be removed from the niche with a small, slightly bent, sharp spoon (Fig. 236, *b*), and a slight improvement could be obtained.

The operative procedures on the niche of the round window, described here, were followed in no case by a reactive inflammation. The author considers them indicated in all cases of exhausted middle-ear suppuration associated with a marked diminution in the hearing in which the niche of the fenestra cochleæ is visible. At times synecho-tomy of the crura of the stapes was combined with the operative procedures on the niche of the fenestra cochleæ, but the results, as a rule, were very unsatisfactory.

According to Kessel, tenotomy of the tensor tympani muscle is indicated after an exhausted middle-ear suppuration if there is a central, kidney-shaped, persistent perforation of the membrana tympani, and if the handle of the malleus, which is greatly drawn inwards, is accompanied by a marked disturbance in the hearing.

If the tendon of the stapedius muscle appears embedded in the cicatricial tissue surrounding the niche of the oval window, and if it is visible on the surface of the scar as a whitish band running backwards from the head of the stapes, we can also make an incision through the tendon when severing the cicatricial tissue.

a b c

FIG. 236.

Multiple incision of flaccid cicatrices of the membrana tympani is indicated if, in retracted scars, the deafness is improved by the outward bulging of the cicatrix, and if the former degree of disturbance of hearing again returns when the scar sinks back into its former position. In these cases circumscribed thickenings are produced in the flaccid scar by multiple incisions, whereby the resistance and, at the same time, the vibratory power of the entire membrana tympani are considerably increased.

The results obtained in the intratympanic operations show that in the majority of cases the improvement in the hearing disappears entirely or in part, while in some exceptional cases, however, it remains permanently. From these facts, as well as from from the occasional disappearance of the subjective noises and dizziness, we are justified in giving them a trial, and especially as they are not as a rule associated with any marked inflammatory reaction.

Lermoyez and Mahu (*Ann. d. mal. d. l'oreille*, 1907) proved that the subcutaneous injections of thiosinamin and fibrolysin in the non-suppurative middle-ear affections were of no value, and thereupon recommended the local use of thiosinamin as daily instillations into the external meatus (30 drops of a solution of thiosinamin 15·0, antipyrin 7·5, aqua dest. 100·0, allowed to

remain in the meatus ten minutes), combined with Delstanche's pneumo-massage three times a week. If, after two to three weeks, no improvement is noticed, several minims of the same drug are injected into the middle ear through the Eustachian tube by means of the catheter. The time of treatment lasts three to six weeks. In several cases the above-mentioned authors are supposed to have obtained satisfactory results with this treatment, but acknowledge, however, that the thiosinamin alone does not yield any result without the mechanical treatment.

The Methods employed to produce a Cicatrix to close a Perforation of the Membrana Tympani.

Closing a perforation in the membrana tympani by creating a cicatrix has the advantage that an increased number of sound waves reach the ossicular chain, and the mucous membrane of the cavum tympani is protected from external harmful agencies and infection. Nevertheless, it must not be lost sight of that cicatrization of a perforation in the membrane may, in some cases, impair the power of hearing. This is particularly so when obstacles to the conduction of sound exist on the malleus and incus, and when the union between the stapes and incus is broken by the loss of the long process of the incus. In these cases the sound, which falls directly upon the foot-plate of the stapes when the perforation is permanent, can no longer do so. Another fact, which has been established by clinical experience, shows that sometimes after closure of the perforation a high degree of deafness, associated with tinnitus, is observed, which disappears only after the re-establishment of the hole in the drum.

When, therefore, an attempt to close the opening in the membrana tympani is made, one must first ascertain if, after a cicatrix has formed, there will be no change for the worse. It therefore behoves us to stop up small perforations with a little glycerine on the point of a probe, and larger openings with a piece of cotton, and then to test the hearing. If the hearing distance is thus increased, or at least not diminished, an operation for closure of the perforation may then be undertaken.

Multiple incision of the edges of the perforations, as already recommended; cauterizing its margins with silver nitrate; covering the perforation with a thin piece of paper, as proposed by Blake, for the purpose of inducing the formation of a cicatrix; the transplantation of a piece of skin (Ely); and the application of a fresh piece of skin of a chicken's egg (Berthold*), have only rarely given a satisfactory result.

Of the methods hitherto used, cauterization of the edges of the perforation with trichloracetic acid, as recommended by Okuneff, 1895, has proved of most value. His assertions that dry perforations were made to cicatrize in nearly 80 per cent. of cases were confirmed by Gomperz, Spira, Blau, Biehl, Barnick, and Wasmund. Touching with trichloracetic acid is indicated

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* *Die ersten* 10 *Jahre der Myringoplastik,* 1889.

in all old, dry perforations. This procedure is contra-indicated when the membrana tympani is defective in its entire extent, and in perforation of Shrapnell's membrane.

The trichloracetic acid is applied in the following manner: First a piece of cotton, soaked in a 10 per cent. solution of cocaine, is introduced into the perforation and allowed to remain for ten minutes; then a small applicator covered with a thin layer of cotton is dipped into a concentrated solution of the acid, and applied to the free edges of the perforation. Upon touching the edges of the perforation a white eschar forms, which falls off within a few days. Even after one to two applications, it usually is noticed that the perforation has grown smaller. The cauterizations should be repeated at intervals of from four to eight days, the number of applications varying according to the size of the perforation. Care must be taken that the acid is not used too freely, as it sometimes sets up a rather marked inflammatory reaction.

It is extremely difficult to keep perforations open which have a tendency to close, and fails in the majority of cases. Such a procedure is indicated when, through temporary closure of the perforation by secretion, by an epidermic mass, or by the formation of a cicatrix, there is a striking decrease in the hearing power, which disappears again when the perforation is re-established.

Purulent Middle-Ear Inflammations arising in the Course of the Infectious Diseases.

Purulent Middle-Ear Inflammation arising in the Course of Typhoid Fever.

The mild, non-perforative middle-ear catarrhs, with a serous, mucous, muco-purulent discharge in the middle ear, are, on the whole, not uncommon in the course of typhoid fever. They usually disappear after the disease has run its course, or form the bases of later adhesive processes. During the typhoid process they do not give rise to any marked symptoms, and become evident only in the stage of convalescence. The disturbances of hearing which accompany the typhoid middle-ear catarrhs, and which are often of a high degree, are undoubtedly caused by simultaneous changes in the labyrinth or by the action of the typhoid infection on the auditory nerve, or on the hearing centre. Hassler found typhoid bacilli in the secretion (this is very rare). The purulent middle-ear inflammation is more often met with in typhoid fever.[*] It was observed by Hoffmann (*A. f. O.*, vol. iv.) four times in 250 cases of typhoid, by Bezold (*A. f. P.*, vol. xxi.) forty-one times in 1,243 cases ($3\frac{3}{10}$ per cent.), by Suckstorff in 7.7 per cent., and by Schuhmacher in nearly half the cases of typhoid in children. The following are the causes of typhoid middle-ear suppuration which usually arises in the fourth or fifth week of the disease: The direct extension of the inflamma-

* *Ueber die im Mittelohrsekrete bei Typhösen vorkommenden Mikroorganismen.* See E. Fränkel and Simonds, *Deutsch. med. Wochenschr.*, 1887.

tion of the mucous membrane of the pharynx and posterior nares, which so often arises in the course of typhoid, to the Eustachian tube and tympanic cavity; the entrance of septic secretion from the naso-pharynx into the middle ear; and the occurrence of emboli in the mucous membrane of the middle ear, which arise either from an endocarditis or from a collection of pus at some other part of the body. The perforation is usually located in the posterior part of the membrane, and is larger at the beginning of this disease than in the ordinary middle-ear suppurations. Hoffmann saw a double perforation and multiple ones in acute cases.

The disturbance of hearing accompanying the suppurative process is often severe on account of the simultaneous peripheral or central affection of the acoustic nerve; this is especially noticeable if the aural trouble arises early in the course of the general disease. It is true that the hearing distance often increases in the convalescent stage; still, it not infrequently happens that a marked deafness continues for some time. The duration of the suppuration is generally more protracted than in the ordinary acute forms, yet it usually terminates within a very short time in cicatrization of the perforation, with complete restoration of the hearing power in persons who are otherwise perfectly healthy. The prognosis of typhoid middle-ear suppuration is relatively better than that of a middle-ear suppuration arising in the course of the other infectious diseases. Nevertheless, we sometimes meet with severe forms which are associated with inflammation and abscess formation in the mastoid, caries and necrosis of the temporal bone, facial paralysis, extension of the suppuration to the neighbouring organs, and total deafness from a panotitis. When we have a case of typhoid, and we wish to avoid the intercurrence of a middle-ear inflammation, it is advisable to keep the nose and post-nasal spaces free from infection by the frequent use of some cleansing antiseptic sprays, or by the instillation of medicated solutions.

The treatment of acute typhoid middle-ear suppurations is not different from that employed in the ordinary acute forms.*

Suppurative Middle-Ear Inflammation in Influenza.

We have already referred to influenza otitis under the descriptions of otitis media acuta, and acute purulent inflammations of the middle ear; the author will, therefore, limit himself in the following remarks to a short synopsis of the clinical appearances and sequelæ of this form of otitis.

In the purulent middle-ear inflammations which arise with marked reactive phenomena at the beginning of an influenza or

* Compare J. Böke, *Les maladies de l'oreille dans le typhus et leur traitément. Brüsseler Kongressber.*, 1888.

during its course, a hæmorrhagic inflammation of the membrane often develops in the initial stage of the disease, which is accompanied by the formation of smaller or larger dark blue or black bullæ. These are situated on the posterior superior segment of the membrane, and, lasting a short time, burst before perforation of the membrane has taken place, discharging their hæmorrhagic serous contents into the external meatus.* A hæmorrhagic or fibrinous exudate arises simultaneously in the osseous or cartilaginous meatus. Perforation of the drum usually takes place in front of the handle of the malleus or in the posterior superior quadrant of the membrane at the apex of a cone-shaped elevation, from which a drop of pus exudes during the Valsalvan experiment (Fig. 159 p. 352). The severe pains which arise before perforation has taken place often continue for some days after perforation without diminishing in intensity. Cases are frequently met with in which neuralgic pains, having the character of otalgia, continue even after the suppuration has run its course. Spira reports a case of influenza otitis which presented the symptoms of a trigeminal neuralgia for several months. Kaufmann observed several obstinate and severe cases of otalgia arise during an epidemic of influenza. Subjective noises, such as beating, hammering, and roaring, are always intense, and continue long after cessation of the inflammation. They may even remain permanently at times, and may be the accompanying symptom of a progressive deafness. The disturbance of hearing, which is usually considerable in the stage of suppuration, may disappear completely after the suppuration has become exhausted. Often, however, deafness of a varying degree remains in consequence of pathological changes in the middle ear and labyrinth. Severe deafness after an influenza suppuration may be attributed to a panotitis; deafness without a diseased condition of the middle ear may be due to changes in the labyrinth, to a neuritis of the acoustic nerve, or to a simultaneous neuritis of the ramus cochlearis. The suppuration is generally more protracted than in the usual acute forms, and passes more often into the chronic state. It has been found that suppurative influenza otitis is very often complicated with abscess formation in the mastoid process and with a simultaneous bulging of the posterior superior wall of the meatus. Spontaneous subsidence of the mastoid abscess is seldom observed, as it often leads to rapid destruction of the bone, which necessitates the opening up of the mastoid in order to prevent dangerous

* Löwenberg (*Bulletin médical*, January, 1890), Schwabach (*Berliner klin. Wochenschr.*, 1890, No. 3), Delstanche and Hennebert (*La Clinique*, Bruxelles, 1890, No. 7), Schwendt (*Basel, bei Werner Rhöm*, January, 1890), J. Michael (*Deutsche med. Wochenschr.*, 1890, No. 6), A. Politzer (*Wiener med. Blätter*, Nos. 9 and 10, 1890), Szenes (*Berliner Kongressber.*, 1890), Jankau (*Deutsche.med. Wochenschr.*, 1890).

complications. The following sequelæ often cause a fatal ending: Extradural abscess, meningitis, cerebral abscess, cerebellar abscess, pyæmia, perisinous abscess, thrombosis of the sigmoid and cavernous sinuses, erysipelas, and nephritis. *Vide* Diseases of the Mastoid Process.

The influenza bacillus discovered by Kitasato is frequently found in the pus of influenza mastoiditis. The primary bacteria giving rise to the affection are, however, soon destroyed by the micro-organisms of the secondary infection, among which the streptococcus is most prominent. According to Haug, those cases leading to mastoiditis are characterized by the marked predominance of the streptococcus and diplococcus.

Lermoyez* expresses the opinion, based on numerous clinical observations, that acute inflammations of the middle ear are contagious. He bases this opinion on the fact that frequently several members of the same family and the attending nurses are affected simultaneously or in rapid succession by a middle-ear inflammation. It is generally due to secondary complications arising in the course of influenza. It must be remarked, however, that the affection is, in rare cases, transmitted to healthy individuals, and that the disease in such cases also assumes the character of the primary inflammation (catarrhal, purulent, or hæmorrhagic exudation) in the infected individual. Lermoyez supports his opinion by the observation of Dr. Barbier, who noticed an epidemic of otitis media amongst otherwise healthy children after he had taken a child, who had been suffering from an acute middle-ear inflammation, into a crèche.

From the foregoing, therefore, Lermoyez considers it a very important prophylactic measure to isolate individuals having otitis media acuta, especially those with the scarlatinal and morbillous forms, until the inflammation has run its course.

The Scarlatinal-Diphtheritic Suppurations of the Middle Ear.

The severest forms of acute suppuration of the middle ear develop in the course of scarlet fever, and particularly if they are complicated with a naso-pharyngeal diphtheria.

Clinical observations have demonstrated that acute suppurative inflammations of the middle ear are of frequent occurrence in scarlet fever, and especially in that form associated with diphtheria. The investigations of Siebenmann, in which he found only one normal middle ear in twenty-five *post-mortems,* show how often the organ of hearing is affected in the severe forms of diphtheria which end fatally.

The diphtheritic process in scarlet fever appears in two forms: (1) True diphtheria, with the formation of a diphtheritic membrane in which the Löffler bacillus is found, and later the staphylococcus, diplococcus, and streptococcus through secondary septic infection; (2) necrotic scarlatinal diphtheria brought about by a marked streptococcus infection. It is especially in this form that one finds the destructive middle-ear suppurations associated with swelling of the glands in the neck.

Primary diphtheria of the middle ear, which is very rare, has been clinically observed by Burckhardt-Merian. Kirchner and Hirsch, who found the middle-ear mucous membrane at the *post-mortem* of two children covered with a fibrinous deposit infiltrated with streptococci, are of the opinion that these were cases of primary diphtheritic inflammation.

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* Lermoyez, *La Contagion des Otites moyennes aiguës.* Transactions of the Sixth International Otological Congress, London, 1898, published 1900.

Lewin (*Archiv für Ohrenheilk.*, vol. lii.), who examined sixty clinical cases of genuine pharyngeal diphtheria bacteriologically, found only one case of true diphtheritic inflammation of the middle ear. In 60 per cent. of his cases he found only mild inflammatory changes in the middle ear, without perforation of the drum. He regarded these of a toxic nature, brought about by hæmatogenic invasion. There seems to be a particular predisposition to this affection in children during the first five years of life.

The scarlatinal-diphtheritic middle-ear suppurations generally develop at the crisis of a naso-pharyngeal diphtheria. Every naso-pharyngeal diphtheria is not, however, combined with a diphtheritic exudation in the middle ear. The inflammation commences with very severe pains, which usually remain some days after perforation of the membrane has taken place. The rise of temperature produced by the naso-pharyngeal diphtheria may be temporarily increased ($39°$ to $40°$ C. $= 102.2°$ to $104°$ F.) by the development of a middle-ear inflammation; in like manner we find that in very young children a mental disorder, delirium, and convulsions may arise in addition to the already existing head symptoms. Swelling of the lymph-glands at the side of the neck is more frequent in this form of disease than in the ordinary forms of otitis.

There is no other form of disease in which the destruction of the membrane with the formation of extensive perforations is so rapid as in the scarlatinal-diphtheritic suppurations of the middle ear. The diffuse destruction of the membrane, which is often visible even on the third or fourth day, is undoubtedly produced by the action of the specific bacteria of this disease.

If one has the opportunity of examining a case of true diphtheria soon after perforation of the drum membrane, it is possible to see the diphtheritic membrane lying in the deeper parts, and often extending into the meatus. This deposit is not easily removed by syringing, and there is also difficulty in removing it mechanically with forceps; when performing the latter manipulation, the underlying surface shows a tendency to bleed easily. The picture is so characteristic that, after a little experience, we are able to make the diagnosis without the least difficulty, especially if we take into consideration the affection of the pharynx existing at the time. Only if the examination is undertaken superficially can the diphtheritic membrane be mistaken for macerated epidermis. When we suspect that the membrane is due to a diphtheritic infection, it is advisable to make a culture and smear of the secretion to ascertain the presence of diphtheritic bacilli. If the culture proves positive our diagnosis is verified, and we can then adopt the proper anti-diphtheritic treatment.

The discharge is generally slight in the first few days after perforation of the membrane, but after the separation of the diphtheritic membrane it becomes very copious, often foul-smelling, bloody, or discoloured. Examination of the drum

membrane reveals a large perforation which involves two-thirds or nearly its entire area, and even when the disease has lasted only a few days the exposed, livid-red, swollen mucous membrane of the inner tympanic wall, the free handle of the malleus, and the incudo-stapedial joint become visible.

Suppuration in this form of inflammation always runs a protracted course, and is sometimes accompanied by pyæmic symptoms. Even where the conditions are favourable, the secretion seldom ceases in less than two to three months. The suppuration runs the most favourable course if the physician is in the position to make an extensive incision in the drum membrane within the first twenty-four hours. A restoration to the normal condition is a rare occurrence, but the author has seen this several times in scarlatinal otitis without diphtheria; in the majority of cases large persistent perforations of the drum remain. The suppuration often becomes chronic, with the formation of granulations and polypi in the tympanic cavity, on the remnant of the membrane, and in the external meatus.

The disturbance of hearing is usually very marked in the acute stage of the process. As the disease progresses, however, the hearing generally improves; still, a marked deafness remains in a large percentage of cases in consequence of the invasion of micro-organisms into the labyrinth. Sometimes, where we have to do with a panotitis or with a necrosis of the labyrinth, total deafness remains, which, if it occurs in children during the first years of life, may form the basis of deaf-mutism. The power of hearing is often only slightly altered even in the severe forms of this disease; the author has seen quite a number of cases in which, in spite of an extensive destruction of the membrane after the middle-ear diphtheria had run its course, whispered speech was understood at a distance of over 6 metres. Paralysis of the soft palate, which remains after pharyngeal diphtheria, leads to obstinate catarrhs of the middle ear owing to an impaired ventilation of this cavity.

Scarlatinal-diphtheritic middle-ear suppuration often leaves deep-seated changes in the organ of hearing. The destructive process not only affects the membrana tympani, but also the check ligaments of the ossicles, which are thus loosened and expelled. Where the ulceration extends to the bony walls of the middle ear, we not infrequently find caries and necrosis of the temporal bone which may lead to exfoliation of smaller or larger portions of the same, and to erosion of the Fallopian canal with facial paralysis; or the necrotic process may bring about a fistula of the labyrinthine wall with destructive changes in the labyrinthine contents, or perforate towards the cranial cavity causing a fatal termination from sinus phlebitis, meningitis, and brain abscess.

Prognosis.—The prognosis of a simple scarlatinal suppuration

of the middle ear is, apart from some severe forms, favourable, as there is usually a complete cure and a return of the normal hearing after the process has run its course. On the other hand, the prognosis of the scarlatinal-diphtheritic infections is unfavourable if they are associated with the above-mentioned complications.

It must be stated, however, that, in spite of the most careful treatment of scarlatinal diphtheria of the middle ear, the development of severe complications cannot be prevented; on the other hand, it is possible in many cases, by a timely treatment, to prevent those severe disturbances which so often arise if the suppurative process is allowed to run its own course.

Treatment.—The treatment of diphtheritic or scarlatinal-diphtheritic middle-ear inflammation must be begun immediately after perforation of the membrane, in order to check the destructive action of the diphtheritic infection. In those cases in which perforation has not yet taken place, paracentesis should be performed as soon as possible. The treatment of diphtheritic middle-ear suppuration is both general and local. If the culture is positive, showing the presence of diphtheritic bacilli, we must immediately give injections of antitoxin. The ear should be syringed several times a day with lime-water, or with some antiseptic solution as boracic acid solution, bichloride solution, etc. O. Wolf recommends the application of Politzer's method in the first stage of the disease, followed by removal of the secretion with cotton, and the instillation of bichloride alcohol 0·1 : 100·0, or resorcin alcohol 1·0 to 1·5 : 100·0; this treatment is to be repeated two or three times a day. When there is a coexisting naso-pharyngeal diphtheria, the ordinary anti-diphtheritic treatment must be given; the usual antiseptic sprays, nasal drops, and local applications must be resorted to in addition to the injection of antitoxin.

Middle-ear diseases arising in the course of measles are of frequent occurrence. According to Sieg. Weiss and Nadoleczny, catarrhal exudates in the middle ear, running their course without symptoms, are found in a large number of children affected with measles. In some epidemics of measles, the suppurative middle-ear inflammations are so severe that they have the destructive character of the malignant forms of scarlatinal diphtheria.* The rapid destruction of the tympanic membrane, the speedy development of granulations in the tympanic cavity, caries and necrosis of the temporal bone, and panotitis are occasionally observed in middle-ear suppurations due to measles.

The suppurative middle-ear inflammation in measles usually arises in the beginning of the affection, but not infrequently only in the desquamative stage. Blau estimates that it occurs in

* Baar, G., *Contribution to the Etiology of Otitis Media Suppurativa post Morbillos. Medical Record*, 1906.

from 2 to 8 per cent. of middle-ear suppurations. The treatment of middle-ear suppurations and their complications arising in the course of measles is the same as that employed in the ordinary acute middle-ear infections as given on p. 364.

Tubercular Disease of the Organ of Hearing.

The occurrence of suppurative middle-ear processes in tubercular individuals, especially in those affected with phthisis, is well known, and has been fully detailed by Rhomberg, Grisolle, Nélaton, Rilliet, Barthez, Geissler, and others. Wilde* also called attention to the clinical picture of tubercular middle-ear inflammation, to its painless beginning, and to the characteristic nature of the pus. The anatomical and clinical contributions of Rokitanski, Virchow, Toynbee, v. Tröltsch, Hammernyk, Zaufal, and others, in reference to tubercular disease of the temporal bone, were all we possessed. It was only in the last decade that greater attention has been paid to tuberculosis of the ear. In the year 1865† the author called attention to the clinical peculiarities of this form of middle-ear suppuration. Schwartze‡ described the seldom-occurring, cheesy infiltration of the mucous membrane, and the presence of tubercle nodules on the membrana tympani, which are usually associated with a rapid destruction of the drum membrane. In the year 1882§ the author published the histological condition of the mucous membrane of the middle ear of a woman who had suffered from a middle-ear suppuration, and who had died of phthisis. The examination showed that a portion of the mucous membrane of the promontory had been destroyed by the tubercular process, and that the disease had also extended into the bone (Fig. 237).

The numerous specimens in the author's collection, taken from patients who had died of phthisis, give a clear picture of the destructive character of tubercular suppurations of the middle ear. In a number of the specimens the membrane is defective to a great extent, or totally destroyed, the ossicles are deprived of their mucous membrane, and so loosened by destruction of their ligaments that they fall out even if gently touched. The walls of the tympanic cavity and antrum resemble macerated bone, and are stripped of their mucous membrane. In another series of specimens the osseous framework of the temporal bone is necrotic to a varying extent, the promontory wall is perforated like a sieve or entirely destroyed, and the labyrinth is exposed. Where the disease is extensive, the petrous bone is entirely or partially necrotic and broken up into several pieces; the carotid canal, the lateral sinus, the mastoid process, and the external meatus are involved in the tubercular destruction; and the dura mater covering the temporal bone is infiltrated, discoloured, and perforated.

We are indebted to Hegetschweiler,‖ Habermann,¶ Barnick,** Schwabach,†† Körner,‡‡ and others, for a complete description of tubercular suppurations of the middle ear. The histological examination of the middle-ear mucous membrane shows swelling, small cell infiltration, tubercle bacilli arranged in groups, giant cells, and destruction of tissue here and there. Tubercle nodules are also found in the granulation tissue.

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* *Practical Observations on Aural Surgery*, 1853.
† *Beleuchtungsbilder des Trommelfells*, 1865, p. 65.
‡ *Pathologische Anatomie des Ohres*, 1878.
§ *Lehrbuch der Ohrenheilkunde*, 1 Aufl., p. 467.
‖ *Die phthisischen Erkrankungen des Ohres auf Grund von* 39 *Sectionsberichten Bezold's*. J. F. Bergmann, Wiesbaden, 1895.
¶ *Zeitschr. f. Heilk.*, 1885, 1888; and *Prager med. Wochenschr.*, 1885.
** *Haug's klin. Vorträge*, 1899.
†† *Berliner Klinik*, 1897.
‡‡ *Zeitschr. f. Ohrenheilk.*, vol. xxx.

Tubercular middle-ear suppuration develops most frequently in patients with pulmonary tuberculosis. It occurs at any stage of the general infection, but mostly, however, in advanced phthisis. In the latter affection it occasionally arises in the last days of the patient's life. Predisposing causes of this disease are hereditary predisposition, unfavourable surroundings, and all forms of cachexia. The author has repeatedly observed its occurrence with tubercular swelling of the glands after an attack of scarlet fever. According to the observations of Schwabach and Hegetschweiler, it occurs much more often in males than in females. Milligan calls attention to the frequent occurrence of
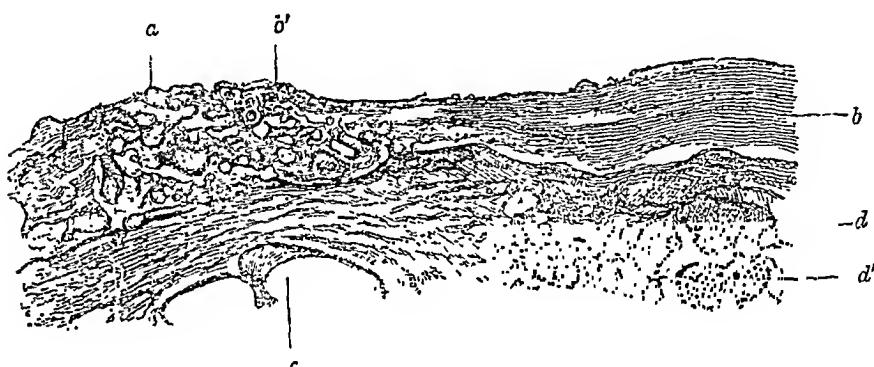
Fig. 237.—Microscopic Section of the Inner Wall of the Tympanic Cavity of a Woman, 36 Years of Age, who died of Pulmonary Tuberculosis, and who had suffered for Four Months from Profuse Suppuration of the Middle Ear on the Right Side.

The anterior portion of the inner wall of the tympanum is completely deprived of its mucous membrane, and the exposed bone is pale, somewhat rough, and uneven. In sections, the boundary of the mucous membrane (*b, b'*), which becomes thinner towards the place where the loss of substance has occurred (*a*), can be distinguished. The bare bone (*a*), the structure of which is sharply set off from the capsule of the cochlea (*c*), lying below it, presents everywhere the characters of inflammation. The remains of the corroded osseous lamella (*a*) project on the surface like small ridges. The vascular spaces, as also the larger osseous spaces (*d, d'*) in the posterior portion of the petrous bone, are filled with round cells.

tuberculosis of the ear among the children of the poor. According to Heike (*Deutsche med. Wochenschr.*, vols. x., xi.), the glands and lymphatics in tubercular infants are more often involved than in adults, and destruction of the bone takes place much quicker.

Primary tuberculosis of the ear, which has been observed by Knapp, Küster, Haug, and others, is rarely met with. When it does occur, it is generally localized in the mastoid process. In the primary forms, the disease may start in the cancellous spaces of the bone by infection from the blood, or in the mucous membranes by invasion from the pharynx through the tube. According to Barnick we find, in addition to marked inflammatory infiltration, numerous tubercle nodules which constantly degenerate and form superficial ulcers which

later extend to the bone.   According to Henrici,* primary tuberculosis of the mastoid usually occurs in childhood—that is, in one-fifth of the cases of mastoiditis in children.

The disease is most frequently caused by invasion of the bacilli through the tube, or along the lymph-channels in its submucous tissue; it is more rarely produced by the entrance of the bacilli from the external meatus through an existing perforation of the membrane.   Infection through the blood may occur in tuberculosis of the glands and bones, or in miliary tuberculosis.

Tubercular disease of the middle ear sometimes occurs with symptoms of an acute middle-ear suppuration, or, as is more commonly the case, takes the form from its very commencement of a chronic suppuration running its course without any inflammatory phenomena.

The condition of the membrana tympani in acute cases after perforation is the same as in the ordinary primary otitis.   In exceptional cases, in which one has the opportunity of examining the membrane before rupture has taken place, one sometimes finds the drum reddened or pink, and presenting at one or more places sharply circumscribed pearl-gray spots produced by the tubercle nodules.   After a short time, and usually within a few days, ulcers form at these spots, which break down and cause the membrane to become perforated at two or three places.   Through the rapid destruction of the tissue, these multiple perforations unite into one large defect, through which one can see the actively secreting greyish or reddened wall of the promontory, which is at times covered with rapidly growing granulations.†

In acute cases arising without any symptoms, examination shows that the pale membrane is covered with a creamy secretion, and softened or perforated in the intermediate portions, or at its circumference.

Blake and Buck (*New York Medical Journal*, 1886) consider the appearance of infiltration and destruction of the posterior superior quadrant of the membrane, unaccompanied by pain, a characteristic symptom of a beginning middle-ear tuberculosis. According to Milligan, the margin of the perforation is gray, softened, and shows no symptoms of a reactive inflammation, as in other chronic middle-ear suppurations.

Symptoms.—The symptoms of acute tubercular suppuration of the middle ear differ only slightly at the beginning of the affection from those of the ordinary acute middle-ear inflammation.   It is only in the further course of the disease that our suspicion is aroused of its tubercular nature, through the presence of double or multiple perforations, through the rapid destruction

* *Die Tuberkulose des Warzenfortsatzes im Kindersalter.*, *Habil.-Schr.*, by Bergmann, Wiesbaden, 1904.

† Cp. Politzer, *Atlas der Beleuchtungsbilder des Trommelfells*, Plate VI., 8 and 9.

of the membrane with the speedy formation of granulations in the tympanic cavity, through the rapid involvement of the glands of the neck, or through the appearance of a facial paralysis. In the chronic forms of this disease we usually find that it appears without symptoms, and that perforation of the drum is rarely preceded by a slight redness or pain.   Our attention is generally called to the affection by a slight discharge from the ear and the presence of subjective noises.   The torpid course of the suppuration may also continue with an extensive carious destruction of the bone, with or without the formation of granulations.   The discharge is either thin fluid, discoloured, or curdy and fœtid.   The hearing distance is often markedly reduced, in spite of the fact that the disease has existed only a short time; this is due to the rapid extension of the process to the labyrinth.   The perception through the cranial bones is lost.   Facial paralysis is occasioned by carious destruction of the facial canal, or by infiltration of the sheath of the facial nerve with tubercle nodules.   Headache and dizziness are seldom met with.

Terminations.—Tubercular suppuration of the middle ear very rarely ends in cure.   It is questionable whether, in those cases which have been reported cured, there was really a tubercular suppuration of the ear, or whether it was simply a suppuration in a tubercular individual.

The diseased condition of the bone brought about by tuberculosis of the middle ear may confine itself to limited areas of the tympanic cavity, to the promontory, or to the ossicles; frequently, however, a large part of the tympanic walls, the large blood channels, the mastoid process, and the petrous bone are involved in the carious process.   If the destructive process extends to the labyrinth, it produces a purulent inflammation, as well as a thickening and partial destruction of the membranous labyrinth; or it may lead to a new connective-tissue formation in the labyrinthine wall and in the semicircular canals.*   The author has repeatedly found osteoporosis and the formation of osteophytes in the neighbourhood of the carious tissue.

Tubercular suppurations of the middle ear occasionally lead to intracranial complications.   The author has often seen the dura and the lateral wall of the lateral sinus exposed to a considerable extent, and surrounded by pus, without giving rise to any manifestations.   Even in cases in which the carious process of the petrous bone is extensive, a fatal termination is usually caused by the phthisis, and less often by a purulent or tubercular meningitis, brain abscess, or sinus phlebitis.

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* In about one-third of the cases of tuberculosis of the middle ear which have run their course with caries and necrosis, and which have been examined at the *post-mortem*, perforation of one or both windows of the labyrinth was found (Habermann, Barnick, Schwabach, Gradenigo, Hänel, and Brieger).

Diagnosis.—It must be emphasized that every purulent discharge from the ears of tubercular patients must not be looked upon as a tubercular process. We are justified in concluding that the middle-ear process is of a tubercular nature only if the purulent inflammation runs its course with a rapid destruction of the membrane without marked reactive phenomena; if the inner tympanic wall shows an extensive loss of its mucous membrane, and feels rough and uneven on probing; and, finally, if tubercle bacilli are found in the discharge. According to Brieger, it is very difficult to make a diagnosis from the clinical symptoms, and even from the examination of the secretion.*

The presence of the tubercle bacillus in the secretion from the middle ear of tubercular individuals was first demonstrated by Esche (*Deutsche med. Wochenschr.*, 1883), and later by Nathan and Ritzefeld. It is present only in small numbers in the secretion, and can easily be mistaken for bacilli of a similar appearance which are found in cholesteatomata. The failure to find the tubercle bacillus in the secretion is no evidence that the suppurative process is not of a tubercular nature. The statement of Nathan (*Deutsche Arch. f. klin. Med.*, vol. xxxv.) that he always found tubercle bacilli in the secretion from the middle ear of phthisical patients is contradicted by Schwabach, Brieger, and others; these authors claim that the bacillus is often absent in the secretion of extensive tuberculosis of the ear, and that such a negative result is no positive proof that the process is not of a tubercular character.† In the course of the affection the *Streptococcus pyogenes* or the *Staphylococcus pyogenes aureus* is found in addition to the tubercle bacillus. This mixed infection changes the clinical aspect of the middle-ear tuberculosis, as in these cases the tubercle bacillus gradually becomes less prominent or is entirely supplanted.

Prognosis.—The prognosis of tubercular middle-ear suppuration is, on the whole, unfavourable; it is more favourable in the primary tuberculosis of the mastoid process. It is especially bad in those cases running an acute course, and in which a facial paralysis arises in the beginning of the affection, and in those cases in which the labyrinth becomes involved. In the chronic cases a copious, discoloured, and fœtid discharge, and the evidence of caries of the tympanic walls must be regarded as unfavourable circumstances. On the other hand, when we meet with individuals with primary tuberculosis—as, for example, a localized affection in the mastoid process of children—cure may be obtained by operative measures. In a like manner, a cessation of the discharge not infrequently takes place in some chronic cases of suppuration in tubercular patients (not phthisical in-

* Gh. Ferreri, *Sulla diagnosi della tuberculosi nelle suppurazione croniche dell' orechio. Arch. italian. di Otologia*, vol. x.

† In order to establish a positive diagnosis, Milligan (*Brit. Med. Journal*, 1895) recommends the inoculation of rabbits with some of the mucous membrane and bone which has been removed. According to Brieger, the positive result only of the histological examination of the piece of tissue taken from the diseased part is of diagnostic value (*Festschr. f. Lucae*, 1905).

dividuals) by a careful antiseptic treatment (syringing with antiseptic solutions and insufflation of iodol powder), and by a change to a milder climate. Such cases are most likely middle-ear suppurations of a non-tubercular nature. In phthisical patients, on the other hand, especially if there is a rapid destruction of the membrane owing to the presence of tubercle bacilli in the pus, the prognosis is decidedly unfavourable, and a cessation of the suppuration may be regarded as an extremely rare occurrence.

Treatment.—When the pulmonary tuberculosis is not advanced, a sojourn in a mild climate and proper nourishment are, in addition to the local antiseptic treatment, the most important factors in bringing about a cure of the local disease. The subcutaneous injections of tuberculin have proved worthless. The treatment is directed mostly to the general systemic condition of the patient. The middle-ear suppuration requires the usually antiseptic irrigations and instillations of medicated solutions, as boracic acid and alcohol, peroxide, etc.

The opening up of the middle-ear spaces (mastoid operation) yields the most favourable results in the primary forms of tuberculosis of the mastoid process; this is especially true in children. From the author's observations (*Londoner Kongressbericht*, 1900) and those of Brieger (*ibid.*), the operation is indicated in cases of middle-ear tuberculosis in which the pulmonary affection is not advanced. In such cases we are not only able at times to cure the local process, but also to bring about an improvement in the general welfare of the patient and a cessation of the pulmonary condition. In individuals with advanced phthisis and in tubercular-necrotic processes, the prospects of the operation are poor. When symptoms of mastoid involvement present themselves, it is advisable to operate as early as possible, as long as the strength of the patient gives us some prospect of recovery. As a rule, the operation has only a palliative effect in weak individuals with a constitutional taint. The bony walls of the abscess cavity usually continue to secrete pus, and are exceedingly slow in granulating. In spite of the operation, we generally find that the necrotic process does not cease; the wound cavity is filled with pale, unhealthy granulations, and the affection has a tendency to spread. As a general rule, mastoid operations in tubercular individuals are slow in healing, and are sometimes refractory to all forms of treatment. It frequently happens that the mastoid cavity must be operated upon several times before a satisfactory result is finally attained.

Lupoid affections of the middle ear are rare. In addition to the cases reported by Gradenigo and the author (p. 220), in which a lupoid ulceration extended from the naso-pharynx to the middle ear, we must also mention the cases of Liares, in which the middle-ear affection arose as a complication to a facial and nasal lupus. The prognosis is unfavourable.

Middle-Ear Suppuration in Syphilis.

Syphilitic inflammation of the middle-ear mucous membrane is most frequently associated with a syphilitic naso-pharyngeal affection, and is brought about by the spread of the specific process *per tubam* into the tympanic cavity. The specific ulcers and condylomata, which extend into the tube, not infrequently produce a stricture owing to adhesion of the pillars of the fauces with the posterior and lateral walls of the pharynx, and in some cases a complete atresia. If the affection reaches the tympanic cavity, it may produce a simple catarrh which may disappear without leaving any vestiges, an adhesive catarrhal process with hyperostosis of the osseous walls of the middle ear, or a suppurative inflammation. The objective symptoms of syphilitic suppuration of the middle ear are almost similar to those of the primary forms. Albert H. Buck described two cases in which, besides a double perforation, there were characteristic signs of syphilis on the membrane, which corresponded in colour, ulceration, diffuse swelling, etc., to a similar condition on the soft palate. The deafness is marked in the majority of cases, and comes on with great suddenness. The course and termination present great variations, inasmuch as by proper general and local treatment a cure may be brought about. If the disease is allowed to go on, it may lead to marked ulceration of the mucous membrane, with caries and necrosis of the tympanic walls, mastoid process, and petrous bone, and with facial paralysis; or the process may end fatally from a brain or sinus affection. However, cerebral complications are more rarely met with in this affection than in the other infectious diseases. The *diagnosis* of syphilitic suppuration of the middle ear is difficult, if we take into consideration the fact that the condition of the membrana tympani and middle ear but seldom presents characteristic symptoms. We are, therefore, rarely in a position to determine whether we are dealing with a true specific middle-ear suppuration, as often non-specific affections of the ear occur in syphilitic persons. The diagnosis of the syphilitic nature of the affection can be suspected only by the rapid destruction of the membrane, and by the sudden or rapid loss of perception through the cranial bones. In order to substantiate our diagnosis, we must always make a Wassermann examination of the blood.

The *prognosis* is favourable only at the beginning of the affection, in the milder forms of the disease, and in persons who are otherwise in a healthy condition; it is unfavourable, however, in old and cachectic individuals, in middle-ear affections complicated with the formation of granulations and polypi, in caries, and in total deafness. The author has repeatedly seen cure follow an energetic general antisyphilitic treatment, even in the severe forms. The local treatment is mainly antiseptic, and the instillation of

various medicaments into the middle ear as in any suppurative middle-ear inflammation. It is needless to state that in this form of disease, as well as in all specific affections of the ear, a general antisyphilitic treatment must be adopted. Since the introduction of salvarsan intravenously, splendid results are obtained, in that the aural symptoms disappear rapidly, and the lost hearing returns within a short time. In some syphilitic patients, however, it has been found that a sudden loss of hearing arises after the administration of salvarsan. This is supposed to be due to a sudden stimulation or awakening of the spirochætæ in the internal auditory canal causing an auditory neuritis due to a specific action on the auditory nerve. In such cases we must again give one or more injections of salvarsan, whereupon the lost hearing usually returns.

In leukæmia, characteristic middle-ear inflammations are occasionally observed, but as a rule the affection involves the internal ear much more often. The changes in the mucous membrane consist partly of a free extravasation of lymphocytes or red corpuscles, and partly of a leukæmic and hæmorrhagic infiltration (Schwabach, Alexander, and Gradenigo). A more or less diffuse hæmorrhagic exudate in the mucous membrane of the middle ear has also been observed in pernicious anæmia (Habermann, Schwabach*).

Aural Affections and Pregnancy.

It is a well-recognized fact that pregnancy has, in a large number of cases, a deleterious influence upon the organ of hearing. This disturbance in hearing varies from a mild impairment to a total loss of tone perception. In reviewing the literature on this subject, we find occasional reference to aural disturbances in pregnancy, in that cases are reported from time to time demonstrating clearly the important bearing that sexual changes have upon the aural mechanism in the female. · It is not only the pregnant state in which the hearing is affected, but we find that other sexual conditions, such as disturbances in menstruation, masturbation, vicarious menstruation, and even miscarriages, exercise a harmful influence on the auditory apparatus. That these facts were well known to the older authors is evident from the writings of Hippocrates, who already at that time called attention to the changes in the ears of pregnant women. Similar observations were detailed by Gregorius Horatius in 1660, and again by Pacillini in 1707. The changes in the ears of pregnant women are generally found in the middle ear, which may or may not be associated with changes in the labyrinth. As we lack autopsy findings in these cases, it is impossible to state what pathological changes take place, so that our diagnosis in such cases is made from the history of the case, from our clinical observations before and after parturition, and from the functional tests.

* *Zeitschr. f. Ohrenheilk.*, vol. xxxv.

Symptoms.—The symptoms show considerable variations; the patients usually complain of head noises in one or both ears which vary in intensity, and a deafness of a mild form which either remains stationary or gradually becomes worse during the pregnancy; this impairment leads in some cases to a high degree of deafness, or even in exceptional cases to a total loss of the hearing function.

Etiology.—The etiology of this form of deafness is still obscure, as we do not possess, as stated above, post-mortem data which would throw any light on this subject. Various opinions have been advanced which, however, have not been substantiated. Lucæ is of the opinion that the deafness is due to the marked loss of blood, in some cases producing a secondary anæmia of the internal ear, as a result of which changes are brought about which may be of a permanent nature. Trautman cannot advance any theory, and feels that it is due to some unknown cause, although it may be the result of a hæmorrhage in the ear during child-birth as the result of an exacerbation of a pre-existing cardiac lesion. A great many aurists are of the opinion that syphilis is the underlying etiological factor. This does not seem to be the case, however, as one sees a large number of pregnant women with impaired hearing, in whom there never was the least trace of syphilis, and in whom the Wassermann test has proved to be negative again and again. Others believe that osteophytes may be formed in the petrous portion of the temporal bone during pregnancy, which give rise to secondary changes in the internal ear. Whether it is due to a marked loss of blood, a hyperæmia, or a hæmorrhage into the labyrinth is also a moot question. Pegot* is of the opinion that this form of deafness is due to the toxæmia of pregnancy—in other words, an auto-intoxication—whereby the toxines exercise a deleterious effect upon the auditory nerve, causing a neuritis which is associated with more or less permanent destructive changes. The writer is inclined to accept this view, but yet cannot reconcile himself to the fact that in the majority of cases the tests show that the cause of the trouble lies in the middle ear, in that we usually find a chronic catarrhal otitis media of varying degree, or a more or less developed otosclerosis. It has been observed that in all cases in which there is a pre-existing impairment of hearing, even of a mild degree, it is often aggravated during and after pregnancy, becoming more intense as the pregnancy advances. It has also been noted that if the patient is left with a deafness in one or both ears, whether the impairment is of a mild or severe form, the hardness in hearing becomes more intense with each successive pregnancy. The writer had occasion to see a young woman who, after her first confinement, developed symptoms of a severe toxæmia, running temperatures

* J. G. Pegot, 'Les Surdites de la Furunculose et de la Grossesse,' *Paris Thésis*, 1901.

as high as 105°, and who became totally deaf in both ears. The functional tests revealed a marked middle-ear lesion, with only a mild involvement of the labyrinth. All forms of treatment were administered, but of no avail, and she has not regained her hearing, which is now a period of nearly a year.

Treatment.—The aural treatment of deafness associated with pregnancy is, in the majority of cases, of no avail. Our local measures have little influence upon the condition in the ear, so that our only hope in preventing a further advance of this affection often lies in the hands of the obstetrician. The local treatment is the same as that employed in the ordinary middle-ear catarrhs. As experience has demonstrated that the aural condition is often aggravated with child-birth, we are frequently confronted with the question whether it is advisable to allow the patient to go to full term, or to induce labour with the hope of staying the progress of the disease. This is a matter which must be carefully weighed in each case, and one must consider well whether, in some instances, abortion is not justifiable.*

The Carious and Necrotic Affections of the Temporal Bone which develop in the Course of Suppuration of the Middle Ear.

Etiology and Occurrence.—The occurrence of ulcerative osseous affections in the course of suppuration of the middle ear is due partly to local changes in the ear and partly to constitutional diseases, such as tuberculosis, scrofula, syphilis, diabetes, marasmus, mercurial and other cachexiæ, and to trauma and new growths. Their frequent occurrence in infectious diseases has already been pointed out. Among the local causes, the most important are the following: Retention of pus in the middle ear due to stricture of the auditory canal and to the formation of polypi, granulations, and cholesteatomata in the tympanic cavity; stagnation, thickening, caseation, and decomposition of the purulent secretion, or the accumulation of epidermic masses in the pneumatic spaces of the temporal bone; and, finally, ulceration of the mucous membrane, which, after exposure here and there of portions of the walls of the cavum tympani, extends to the osseous tissue. That in many cases we have to deal with a disturbance in nutrition in the bone due to disease of the periosteum, and that the caries (ulcerative ostitis)

* Sam. M. Brickner, 'The Unfavourable Influence of Pregnancy upon Chronic Progressive Deafness,' *Amer. Journ. of Obstet.*, vol. lxiii., No. 6, 1911.

W. W. Morland, 'Deafness in Connection with Pregnancy and the Puerperal Condition,' *Trans. Amer. Soc. Boston*, 1869.

Thos. E. McArdle, 'The Influence of the Sexual Life of Women in the Etiology of Certain Diseases of the Ear,' *Trans. Amer. Assoc. of Obstet. and Gyn.*, vol. i., 1888.

is often due to a tubercular, and occasionally to an osteo-myelitic, process in the bone has been fully established by pathological findings.

Caries of the temporal bone is developed less often in acute suppurations of the middle ear—in particular the scarlatinal-diphtheritic, measles, tubercular, syphilitic, and typhoid forms—than in the chronic forms. It occurs more frequently in children than in adults. The osseous affection ranges from a slight superficial circumscribed caries, not larger than a pin's head, to an extensive destruction, involving almost the whole of the temporal bone. The most extensive destructions are encountered in those affections due to scarlet fever and tuberculosis. The pneumatic portions of the temporal bone are more frequently the seat of caries and necrosis than the diploëtic and compact bone substance. Accordingly, the mastoid process and the posterior superior wall of the external meatus are most commonly affected, more rarely the tegmen tympani, the promontory wall, the pars petrosa, the anterior wall of the meatus, the pars squamosa, the labyrinthine capsule, and the apex of the petrous bone. The process may be confined to one of the parts just mentioned, or diferent areas may be involved.

A portion of the temporal bone which may be the seat of caries is the inferior tympanic space. The assertions of Kretschmann and Grunert that the walls of the so-called cellar (*cavum hypotympanicum*) are also occasionally the seat of caries can be confirmed by the author by specimens in his collection. The ulcerative process extends comparatively seldom to the lateral sinus and to the carotid artery, in spite of the fact that the cell spaces of the cellar extend from the inferior anterior wall of the meatus to the carotid canal. Hence, in opening the middle-ear spaces, one must not forget to thoroughly explore these regions.

The carious processes arising from the middle ear lead, through degeneration and absorption of the osseous tissue, or through necrosis and exfoliation of large osseous masses, to the formation of large defects in the temporal bone, in consequence of which extensive communications are produced between the meatus, mastoid process, and tympanic cavity. Simultaneously in other parts, especially in the osseous tissue surrounding the carious portions, the cavity is considerably contracted by diffuse, sclerosed, or more frequently by flat, reticular, fenestrated osteophytes. Besides caries, the author very often found the latter form of bone formation in the larger air-spaces of the mastoid process. In other cases the spaces are first filled with granulation tissue, which later ossifies into a solid mass.

In addition to caries of the temporal bone, one generally finds extensive changes in the lining membrane of the middle ear and of the meatus, as well as in the membrana tympani and ossicles.

The mucous membrane is not infrequently either ulcerated, or changed into spongy granulation tissue, which may either partly or entirely fill the middle-ear spaces, and grow out into the meatus, or it may be studded with polypoid proliferations. Experience has shown that it is the dirty-gray, discoloured granulations which are filled with micrococci, and spring from carious bases in the neighbourhood of cario-necrotic areas, that grow again after removal. The lining membrane of the meatus appears infiltrated, undermined, or loosened; the membrana tympani is destroyed to a great extent, or has undergone polypoid degeneration (v. Tröltsch), or its remnants have become adherent to the inner wall of the tympanic cavity, while the ossicles may be loosely articulated, carious, or exfoliated. The spaces not filled with proliferations of mucous membrane contain offensive, caseous masses of cholesteatoma, or ichor mixed with blood, cholesteatomatous masses, and exfoliated spicula of bone.

Symptoms of Caries of the Temporal Bone.—Pain, increasing especially at night, is the most prominent of the subjective symptoms accompanying caries of the temporal bone. This is sometimes very intense even with small circumscribed bony ulceration, while cases of extensive caries and sequestrum formation, especially in tuberculous and scrofulous persons, may run their course without any pain. The pain is caused either by inflammation of the periosteum and of the bone accompanying the ulcerative process, or by the retention of secretion, in which case the most intense pain often quickly subsides if the pus escapes spontaneously or is removed by operative measures. When the sequestrum has completely formed, the pain often ceases. Obstinate pain, however, may be caused at times by an angular, loose sequestrum of the mastoid process or labyrinth, which has not yet been completely cast off or has become impacted. As a rule, the pain ceases only after the dead bone has been removed. At times, when there is a localized caries, neuralgic pains are experienced in the parts supplied by the trigeminus nerve.

The following are frequent, though by no means constant or characteristic, symptoms of caries: Severe subjective noises, dizziness and vomiting, stupor, great irritability of the nervous system, mental excitement and sleeplessness, accelerated pulse, an occasional chill, and a rise in temperature especially towards evening. Tinnitus and dizziness, which are present at the beginning of a labyrinthine necrosis, entirely disappear after the demarcation of the sequestrum.

The objective symptoms of caries of the temporal bone are of much greater importance. These, however, are by no means always so pronounced that we may come to the conclusion that an ulceration or necrosis is present. For this reason the nature of the discharge, the changes in the external meatus and in the

neighbourhood of the ear, and not infrequently the simultaneous functional disturbances in the course of the facial nerve, are important in allowing us to assume with great probability that we are dealing with a localized caries of the mastoid bone.

The discharge, especially when the caries is extensive, is very copious and of a thick, cream-like character; often, however, it may be thin like meat-juice, bloody, of a bad colour, irritating, and, in spite of antisepsis, offensive. The suppuration may at times temporarily stop, or suddenly cease entirely, if the escape of the secretion is prevented by constriction of the meatus, by granulations, or by the impaction of a sequestrum.

The changes in the external auditory canal accompanying caries are diffuse swelling, infiltration and ulceration, with the rapid formation of granulations and polypoid proliferations which spring from the edges of a carious fistula. The frequent occurrence of bulging of the cutis of the superior and posterior walls of the meatus is of special importance from a diagnostic standpoint. This is caused either by the spreading of the suppuration of the middle ear to the pneumatic and diploëtic spaces of the superior wall of the meatus, or by the extension of an inflammation from the mastoid process to the posterior superior wall of the osseous meatus. In consequence of the undermining and separation of the cutis produced by the accumulation of pus and cholesteatomatous masses, a sinking of the superior wall of the meatus ensues, which leads to a complete occlusion of the lumen of the canal. The frequent recurrence of such a sinking of the wall must be looked upon as an unfavourable complication of a chronic suppuration of the middle ear.

Bulging of the superior posterior wall of the meatus generally develops with violent pain, seldom without. This sinking disappears either spontaneously, or, often after some weeks, rupture of the cutis takes place with a discharge of fluid or caseous pus, cholesteatomatous masses, or necrosed pieces of bone of the meatus and mastoid process. In rare cases parts of the cartilage of the auditory canal are laid bare by the suppuration, so that its jagged edges project freely into the lumen of the meatus.

By carefully probing one can ascertain the length and direction of a fistula, the locality and extent of the destructive process, and at the same time detect the presence of sequestra.

In consequence of caries of the temporal bone, there often develops an extensive swelling of the lymph-glands on the side of the neck, as well as inflammatory areas and abscesses in the neighbourhood of the ear. These are mostly located on the external surface of the mastoid, or on the parts inferior or posterior to it; the parts in front of the ear are less often involved. They arise either from direct extension of the inflammatory process in the temporal bone to the surrounding soft parts, or by trans-

mission of the inflammation through some existing channel (places of union between the cartilaginous and osseous meatus, the incisuræ Santorini, dehiscences in the os tympanicum, peritubal connective tissue, emissarium mastoideum, etc.); less often, however, they develop without any immediate connection with the diseased part in the temporal bone, by extension of the inflammation through the blood and lymph-vessels, to the soft parts surrounding the bone. Not infrequently these abscesses bore their way down below the region of the ear to the neck, and extend into the thoracic cavity, almost always following the course of the spaces formed by the deep cervical fascia.*

The objective signs of caries vary greatly. Sometimes the region of the mastoid process is found to be greatly infiltrated, swollen, hard or fluctuating, and the auricle, which may be normal or else markedly infiltrated, is seen to stand away from the head; sometimes, however, when the pus has collected in the soft parts surrounding the inferior wall of the meatus, or when the abscess in the bone has discharged into the tissues internal to the mastoid, there develops a hard, painful swelling, extending over the lateral cervical region, which is caused by the infiltration of the parotid gland and of the connective tissue beneath the cervical fascia. Sometimes the inflammation spreads to the occipital and cervical regions (with contraction of the cervical muscles), and at times to the vertex and to the face. Erysipelas, associated with great œdema of the face and eyelids, sometimes occurs in the region of the ear, which may spread to the face, to the other side of the head, and along the neck to the thorax and the arm.

If the process goes on to the formation of an abscess in the parts surrounding the ear, the pus either makes its way into the external meatus by bursting through the cartilage itself, through one of the fissures of Santorini, or through the membranous part of the cartilaginous meatus; or it works its way to the skin of the external region of the ear, and breaks either behind, in front of, or above the ear, and discharges externally. In exceptional cases the pus makes its way inwards towards the naso-pharyngeal space, where it can result in a retro-pharyngeal abscess. In one of the author's cases the caries of the temporal bone was associated with caries of the bodies of the cervical vertebræ. Gherardo Ferreri frequently saw a middle-ear suppuration in children extend to the parotid gland and to the joint of the inferior maxillary bone. In some cases the abscess breaks through, forming a fistulous opening, which often remains for years—in fact, until the diseased condition of the bone heals spontaneously or is exposed by operation.

There is a great diversity in the site of these fistulous openings, which are often very obstinate to treatment, and are filled

* Leidler, *Archiv f. Ohrenheilk.*, 1903.

with unhealthy granulations.   They are most frequently found
around the mastoid process, and occasionally beneath the
auricle, less often above the auricle and in front of the tragus.
Sometimes the fistulous canals communicating with the carious
cavity in the temporal bone discharge their contents at a distant
part, such as the occiput, the cervical region, or, as in a case
observed by the author, in the supraclavicular region.   The
number of fistulous openings also varies.   Often there is only one
opening, but sometimes there are several fistulous openings,
which are situated closely together or at some distance from each
other, which communicate either directly with each other, or
empty into one common carious cavity.

Frequent symptoms of caries developing during the course of
a middle-ear suppuration are paresis and paralysis'of the facial
nerve.   These conditions are most frequently observed in the
scarlatinal-diphtheritic, tuberculous, and syphilitic forms of
middle-ear suppuration.

Paralysis of the facial nerve is caused:

1. By an inflammation extending to the Fallopian canal, and
to the sheath of the facial nerve, without caries of its osseous
canal (neuritis and perineuritis).   These are the most favourable
forms of facial paralysis, because after the inflammation in
the Fallopian canal has subsided, and after the exudate has been
absorbed, the paralysis completely disappears.   A dehiscence in
the Fallopian canal does not necessarily favour the development
of facial paralysis, for it has been found that, in caries and necrosis
of the walls of the cavum tympani, the facial nerve may lie free
in the tympanic cavity completely surrounded by pus, without
any symptoms of facial paralysis ever having been observed during
the life of the patient.

According to the author's observations, slight facial paralyses, perceptible
only on close examination, are rather frequent in simple cases of chronic
suppuration of the middle ear.   Of all the cases of suppuration of the middle
ear seen by Bezold, only 1 per cent. had a marked facial paralysis.   That
facial paralysis sometimes occurs even in cases of simple, non-perforating
catarrh has been proved by the observations of Wilde, v. Tröltsch, Tillmanns,
Politzer, etc.

2. By extension of the destructive process to the facial nerve
itself, which loses its function either through micro-parasitic
or tubercular infection, or through erosion.   Facial paralysis is
seldom caused by a hyperostosis of the facial canal, which has
developed during the course of a chronic middle-ear suppuration.

The facial nerve is most frequently affected in necrosis of the labyrinth.
The cases of labyrinthine necrosis which Bezold collected from the otological
literature showed that the facial nerve was involved in 83 per cent. of
the cases.   This nerve runs the greatest risk of destruction when the
labyrinth is thrown off in its entirety as a sequestrum in necrosis of the upper

part of the vestibule, and in caries of the posterior part of the inner tympanic wall surrounding the Fallopian canal. Facial paralysis is less often observed, on the other hand, when the necrosed cochlea is thrown off.

3. By injury of the facial canal during the radical mastoid operation.

Facial paralysis is generally unilateral, and very rarely bilateral. A peculiarly rigid and immovable expression of the face is characteristic of such a bilateral total facial paralysis.

The degree of facial paralysis varies; this depends on whether the transmission is interrupted in certain bundles, or in the whole nerve-trunk. In the former case the different branches of the facial nerve are unequally affected, and one therefore finds that the paralysis is sometimes most pronounced in the upper branches— that is, in those extending towards the forehead and orbicularis palpebrarum—and sometimes in the lower branches, or, in other words, in those extending towards the nose and angle of the mouth. As a rule the orbicularis palpebrarum is less often affected than the muscles of the angle of the mouth and of the nose. General, though slight, paresis of the facial nerve points to a diminished conducting power in the whole nerve-trunk. On the other hand, complete and persistent paralysis affecting all the ramifications of the nerve allows us to assume that there is a deep-seated lesion and an interruption in the conducting power of the nerve. Réthi has proved experimentally that the levator palati mollis is not supplied by the facial, but by a branch of the pneumogastric nerve.

The reaction to electricity of the paralyzed nerves and muscles is, in the milder forms, either normal or somewhat exaggerated. In the more severe forms the muscles exhibit an abnormal reaction. The faradic contractility of the muscles, which is frequently increased at the beginning of the disease (Erb, Benedikt), rapidly diminishes in the further course of the affection until it is completely lost, while the muscles respond more strongly to the galvanic current than those of the normal side. In a later stage, in advanced atrophy of the nerve and muscles, the galvanic contractility also entirely disappears. When recovery or material improvement takes place in the more severe forms of this affection, the electric reaction, according to Benedikt, returns in inverse order to that in which it is lost.

Severe pain in the ear and in the corresponding side of the face often precedes the development of a facial paralysis; in other cases not the least pain is experienced, and the paralysis is ushered in by twitchings of the facial muscles (spasmodic tic). Finally, the paralysis may come on quite suddenly without any premonitory symptoms. During the course of the affection, one observes marked fluctuations in the degree of the paralysis. If improvement or cure takes place, it does not always occur uniformly in all the parts supplied by the facial nerve, so that some of the branches remain paralyzed longer than others.

The terminations of facial paralysis are:

1. A return to the normal function, in cases in which the inflammation which spreads to the neurilemma, or nerves of the face, completely subsides.

2. Persistent paresis of the whole nerve, or of certain of its branches, when through thickening and subsequent contraction of the neurilemma the conducting power of the nerve is impaired, or when individual bundles of the nerves have lost their function.

3. Complete and persistent paralysis of the facial nerve, when the conducting power of the nerve-trunk has been entirely destroyed by ulceration, or by the formation of indurated masses. The consequences of such a paralysis are secondary atrophy of the facial muscles; permanent conjunctival catarrh, and, when the corresponding side of the palate is paralyzed, secondary catarrh of the middle ear on the previously healthy side, owing to the impaired action of the muscles of the tube.

Prognosis.—The prognosis of an otitic facial paralysis depends on the anatomical conditions and upon the duration of the paralysis. It is most unfavourable in extensive sequestra formation of the petrous bone and in tubercular middle-ear suppurations. The rapid development of a total paralysis with an objective, demonstrable caries and necrosis makes the prognosis unfavourable. A relatively favourable prognosis can be given in the paralysis arising during a radical mastoid operation if the regeneration of the nerve is not hindered by the interposition of a splinter of bone between the cut ends of the nerve during the operation.

Important, from a prognostic standpoint, is the differential diagnosis between rheumatic and otitic facial paralysis, inasmuch as a rheumatic paralysis may arise during the course of a non-suppurative or suppurative middle-ear affection. From the observations made at the author's clinic Neumann (*Wiener med. Wochenschr.*, 1903) found that the rheumatic paralysis arises suddenly, and affects all the branches of the nerve—in particular that branch supplying the angle of the mouth—while the otitic facial paralysis develops slowly, usually effecting one branch after the other.

Although, according to what has just been said, the prognosis of otitic facial paralysis is not always unfavourable, still its appearance in the course of a suppuration of the middle ear must always be regarded as a serious symptom, in so far as it is often the forerunner of a more serious complication. A long-continued, normal reaction of the nerve to electric irritation (constant current) is generally regarded as a favourable symptom. On the other hand, the rapid development of the reaction of degeneration is to be looked upon as an unfavourable symptom.

The galvanic treatment should be used only when the symptoms of reaction have disappeared, and if there are no

other threatening phenomena. The result is frequently favour-able, as the author has repeatedly seen cases in which facial paralyses of long standing were cured or decidedly improved with the galvanic current. When the paralysis has existed a long time, especially after the caries and suppuration have been cured, and the lack of degeneration is due to a destructive or callous formation, it is self-evident that treatment of any kind remains fruitless, and the application of the electric current can in such cases only serve the purpose of checking the atrophy of the muscles of the affected side.

In the last few years it has been tried, based on the experiments on animals carried out by Manasse, to restore the function of the paralyzed facial nerve by uniting it with the nervus accessorius or with the hypoglossus. For this purpose the peripheral end of the accessorius or hypoglossus is dissected out, and the facial nerve is exposed as far as the foramen stylo-mastoideum. The facial nerve, which is severed as high up as possible, is now united with the accessorius or hypoglossus through a lateral incision, and the wound closed up. A result of this union is often noticeable only after several months. Ballance recommends cutting the facial nerve as high up as possible after having chiselled away the lowest portion of the Fallopian canal.

The results of these operations are, on the whole, rather unsatisfactory. When the facial is united with the accessorius, and the facial is put into action, annoying movements are observed in the muscles of the shoulder; when it is joined to the hypoglossus, paralysis and atrophy are noticed in the corresponding half of the tongue.

Diagnosis of Carious and Necrotic Processes in the Temporal Bone.—The diagnosis of caries and necrosis of the temporal bone can be made if the carious spots in the meatus or in the tympanic cavity, which appear pale, grayish-yellow, or discoloured, feel rough on probing, or if sequestra of bone are visible in the meatus or in the deeper parts. On the other hand, the diagnosis is very difficult, and often impossible, if the affection is deeply seated and inaccessible, and if there is an absence of striking symptoms. In those cases in which the denuded osseous tissue is so overgrown with granulations that caries or a sequestrum cannot be seen with the naked eye, the diagnosis can be made only by probing.

It is very important when using the probe in the tympanic cavity to exercise the utmost care. If this precaution is neglected, it is not only possible to dislocate the ossicles, but one is apt to perforate the promontory wall, which is often corroded and soft. The consequences of such a perforation may be very serious, as the pus may find its way into the labyrinth, and extend from there to the cranial cavity. In addition, careless probing may also cause dangerous consequences by opening some of the spaces in the diploë, into which the ichorous pus penetrates, thus finding an easy entrance into the venous passages in the skull and into the general circulation.

When examination with the probe yields no positive result,

caries may be assumed to exist from the following symptoms: Persistent or frequently-recurring pain in the ear, which increases when percussing the mastoid process; a copious, offensive discharge, which is often like meat-juice; a discharge which contains small particles of bone; a continuous or oft-recurring infiltration and sinking of the lining membrane of the osseous meatus; polypi or granulations growing rapidly from the tympanic cavity; and the frequent formation of abscesses in the region of the ear, which do not heal, and leave fistulous openings. Obstinate suppurations of the middle ear, without the above-mentioned objective and subjective symptoms, may also allow us to assume the presence of a carious area. Still, such suppurations, which resist all local treatment, may also be caused by cholestestomata, and by a suppurative process at some inaccessible part of the temporal bone.

Prognosis of Caries of the Temporal Bone.—The prognosis of caries depends on the character, the seat, and the extent of the osseous affection. It is more favourable in healthy individuals, when the affection is superficial, and when the local conditions allow the escape of the secretion, the removal of the sequestrum, and the employment of a rational antiseptic and surgical treatment. On the other hand, the prognosis is unfavourable in tuberculosis, scrofula, syphilis, diabetes, marasmus, and cachectic individuals; furthermore, in deep-seated caries of the pyramid and tegmen tympani, in strictures of the external meatus, in abnormal adhesion between the membrana tympani and inner wall of the tympanum, and, finally, when there is an extensive formation of granulations in the tympanic cavity which prevents the free discharge of the septic secretion.

The extent of the osseous affection does not allow one to say whether the prognosis will be fatal or not, as sometimes a circumscribed caries confined to the roof of the tympanum leads to rupture into the cranial cavity, while in extensive caries reaching to the dura mater and the sinus, a greater part of the temporal bone may form a sequestrum and be ejected without causing a fatal result. When the caries and necrosis are extensive, the hearing function is generally very seriously impaired; this is due to the extension of the inflammation in the bone to the labyrinthine capsule. In these cases, when performing Weber's test, the tone of the tuning-fork is heard in the ear which is not affected, thereby demonstrating that we are dealing with a labyrinthine suppuration.

Course and Termination of Caries of the Temporal Bone. —Caries of the temporal bone develops either suddenly, with a rapid destruction of tissue and the formation of a bony sequestrum (especially in the tubercular, scarlatinal-diphtheritic, and syphilitic middle-ear suppurations), or it runs an insidious course, and ends only after months or years in the formation of a sequestrum. A rapid extension of the process is observed

in children in the first years of life. Not infrequently an occasional pause ensues during the course of the affection, followed by an exacerbation of the destructive ostitis. Such a relapse develops either with violent reactive symptoms, or insidiously. The caries may be entirely cured at one part of the temporal bone, and break out again after some months or years at another part, or in the immediate neighbourhood of the former inflammation.

The terminations of caries and necrosis of the temporal bone are:

1. Recovery, without any material change in the temporal bone. Such an issue is observed in caries and absorption of the superficial osseous lamellæ of the external meatus and of the middle ear.

2. Recovery, with permanent loss of osseous tissue. The loss of substance in these cases occurs either from a gradual absorption of the osseous tissue spreading from the surface to the interior, or from the confluence of the cavities of the temporal bone, as a result of the exfoliation of necrosed fragments of bone in the form of irregular, rough, and sometimes fenestrated sequestra.

3. Extension of the carious suppuration to the facial canal, cranial cavity, and venous sinuses, terminating in death from meningitis, abscess of the brain, and sinus phlebitis (*vide* chapter on Intracranial Complications, p. 567).

4. Erosion of the walls of the carotid canal and lateral sinus, with a fatal termination from hæmorrhage.

5. Death, due to the entrance of septic material from the cario-necrotic parts of the temporal bone into the blood (pyæmia, general septicæmia), or from a general infection taking its origin from the focal affection (tuberculosis, marasmus, albuminuria, amyloid degeneration of the internal organs).

The formation of a sequestrum in the temporal bone generally takes place slowly, but does sometimes develop very rapidly, as in the scarlatinal-diphtheritic forms of otitis. By the retention of the sequestrum in the carious cavity, the profuse suppuration and the formation of new granulations are often kept up, which, after removal of this fragment of bone, generally subside immediately. Violent pains, convulsions, dizziness, and vomiting often cease upon the removal of the sequestrum. Sometimes the sequestrum wanders from its original position.

The size and form of the sequestra depend on the site and extent of the caries. Often only one sequestrum is found, but not infrequently there are several disconnected fragments of exfoliated bone. In children the caries develops more rapidly and more extensively than in adults.

According to the author's observations, circumscribed superficial necrosis of the walls of the tympanic cavity most commonly affects the external osseous layer of the promontory; this lamella, lying beneath the granulating mucous membrane, is cast off in the form of a thin, serrated plate, on which sometimes a part of the sulcus Jacobsonii is found. In other cases there is a necrosis in the bone of the promontory, which penetrates to the lamella of the labyrinth without any demonstrable loss of bone tissue, and is due to an ulcerative

destruction of the mucous membrane. Such an ulcer has a worm-eaten, ragged appearance, owing to the numerous ridges and depressions of the inner wall of the tympanum.

More extensive and of greater importance are the sequestra in deep-seated caries. These are scarcely ever confined to one portion of the temporal bone. At times they involve parts of the meatus and mastoid process, or parts of the mastoid process and pyramid, or a greater part of the temporal bone with parts of the meatus, squamous bone, mastoid process, and labyrinth.

The literature of otology is rich in examples of sequestration and spontaneous exfoliation of large parts of the temporal bone. Not infrequently a single part or the whole of the labyrinth is cast off. The cochlea, the semicircular canals, or the entire labyrinth are occasionally cast off as a sequestrum. According to Bezold (*Archiv f. Ohrenheilk.*, vol. xvi.), about 20 per cent. of the cases of labyrinthine necrosis die from consecutive brain and sinus affections.

Labyrinthine necrosis produces complete deafness. Nevertheless, in erosion of the semicircular canals, the perception for sound may still be preserved if the pus has not extended to the cochlea. After necrosis and exfoliation of the cochlea, perception for speech and tones is lost. The statements that perception for speech and musical tones is still present after exfoliation of the cochlea are misleading, because, in a unilateral affection, the hearing of the other ear cannot be entirely excluded during the hearing-tests. The observations of Burckhardt-Merian, Kretschmann, and the author, that Weber's test is sometimes lateralized to the ear in which the cochlea has been exfoliated, is difficult to explain.

The symptoms accompanying labyrinthine necrosis, such as complete deafness, dizziness, and vomiting, are of diagnostic value only if a sequestrum can be felt in the deeper parts of the ear with the probe, as these same symptoms may also arise when pus enters the cavity of the labyrinth. The diagnosis of labyrinthine necrosis is made more plausible if these symptoms are accompanied by a paralysis of the facial nerve. According to Herold (*Verhandl. d. Vereins d. Chirurg. Berlins*, 1893), disturbances of equilibrium may be wanting when the entire labyrinth is sequestrated.

That, in spite of extensive destruction of the petrous bone reaching almost to the dura mater, complications causing death do not always occur is explained by the fact that proliferations of connective tissue are developed around the sequestrum, whereby a protecting wall is raised against the suppurative process. This is clearly shown by the proliferation of connective tissue in the internal meatus, as observed by Wendt, which, in the case of a sequestrum of the pyramid, prevented the suppuration from spreading to the base of the skull. Changes, such as connective tissue new growths, hyperostoses, and osteo-sclerosis, are also found in other parts of the petrous bone, at the border line of the cario-necrotic process, and act as a barrier, preventing the spread of the destructive process.

When the sequestrum has been discharged or removed, the cavity formed by the loss of osseous substance is, as a rule, filled up with granulations which ossify after being transformed into fibrous connective tissue (callus). In other cases, even when the sequestrum is still present, the walls of the cavity become covered with scar tissue which, through the invasion of the epidermis of the external meatus, is changed into the matrix of a cholesteatoma.

Besides the formation of cavities in the temporal bone, as mentioned above, there often occurs, through exostosis and hyperostosis, an obliteration of the defect formed by the necrosis and a narrowing and obliteration of parts of the tympanic cavity and of the meatus; sometimes the entire tympanic cavity is obliterated by the new-formed connective tissue, and an atresia of the external meatus has even been known to occur; in such cases the meatus is closed like a cul-de-sac, of varying size, with an unyielding osseous mass. It goes without saying that such changes are usually associated with a disturbance of hearing of a high degree or total deafness.

The Treatment of Carious Processes in the Middle Ear. —In the conservative treatment of carious processes in the temporal bone, it is most important to remove as much of the stagnant secretion as possible by frequent syringing with antiseptic solutions. Owing to the excellent results obtained by operative procedures, the conservative treatment has fallen into the background, and it is now practised only in circumscribed caries of the osseous meatus and of the margo tympanicus. Frequent syringing of the meatus is one of the main factors in limiting the carious process, and in preventing its extension to the cranial cavity. If the external auditory canal is filled with granulations or polypi, they must be thoroughly removed. In narrowing of the meatus due to undermining of the posterior superior wall by pus, extensive incisions should be made in the prominent portions in order to allow the pus or caseous masses to escape. In more extensive narrowing near the membrana tympani, thin elastic tubes should be passed through the narrowed portion, and the secretion washed out with a solution of boracic acid, carbolic acid or lysol, or with a weak solution of sodium chloride ($\frac{1}{2}$–1 per cent.).

Syringing the tympanic cavity through the Eustachian tube with a weak solution of boracic acid or saline solution (see p. 124) has proved of special value. Such injections not only wash out putrid secretion and caseous masses, but frequently bring about a rapid relief of the violent pains in the ear. The author attaches great value to this procedure in the treatment of caries, as, according to his experience, the subjective symptoms are removed more quickly by this method than by any other local therapy.[*] When the pains are intense and cannot be alleviated, one is often compelled to resort to subcutaneous injections of morphine.

Local treatment is seldom successful in curing this disease. Cauterization with trichloracetic acid (10 per cent.) or with the galvano-cautery is of some value only in limited, superficial caries of the walls of the meatus; it should

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[*] Cp. L. Gordon, *Ueber den therapeutischen Werth der Durchspülung des Mittelohrs*, etc. Wratsch, 1884, No. 27.

never be employed in caries of the promontory wall. Kretschmann speaks highly of pencilling the parts with iodol alcohol (iodol 2·0, alcohol 16·0, glycerine 32·0); Aysaguer recommends instillation of lactic acid.

In necrosis of the walls of the auditory canal, curetting the denuded bone by means of small, sharp spoons is successful only when the caries is superficial; if the disease in the bone is more deeply seated, scraping is of no avail. One must not curette too deeply on the superior wall of the meatus, on account of its proximity to the cranial cavity. After having scraped away the diseased bone, the wound should be insufflated with iodoform, iodol, or some antiseptic powder, and the external meatus, having been cleaned and dried, should be tamponed loosely with iodoform, xeroform, or ordinary plain sterile gauze.

Although, in the treatment of caries of the temporal bone, our main object is to combat the destructive process by proper local measures, yet these should always be combined with a proper general systemic treatment. In the case of emaciated persons, suitable tonics should be adiminstered. In cases in which the Wassermann test shows the presence of syphilis, an energetic anti-syphilitic treatment must be instituted. Tubercular cases are usually very refractory to treatment, and as a rule require a change of environment. Mineral water containing the iodides, iodide baths, and a hydropathic treatment are in some instances very effectual in limiting the local affection, as well as in raising the general tone of the system.

The conservative treatment of cario-necrotic processes of the temporal bone is indicated only if an operative procedure is contra-indicated or refused by the patient. In the majority of cases, however, a satisfactory outcome can be obtained only by more radical measures—that is, by a simple acute or a complete radical mastoid operation.

Treatment of Facial Paralysis.—This is the same as the treatment of suppuration of the middle ear and of the carious affections of the petrous bone. If the paralysis commences with violent pains in the ear during the course of an acute middle-ear suppuration, the internal use of large doses of iodide of potassium (0·5–1·0 gramme daily) is of great value. This internal medication may be augmented by rubbing ointments of the iodides, to which morphine or the fluid extract of laudanum has been added, on the mastoid process and in the vicinity of the ear.

Caries and Necrosis of the Ossicles.

Caries of the ossicles develops either independently, or is associated with necrosis of other parts of the temporal bone. The disease may be confined to one of the ossicles, or it may affect the entire chain. When the caries is limited to one of the ossicles, the incus is affected more often than the malleus. Caries

of the head of the malleus is often associated with caries of the body of the incus. In such cases the osseous affection penetrates into the deep parts, usually starting from the inner surface of the malleo-incudal articulation (Fig. 238). The destruction is sometimes so great that one finds either a small jagged remnant of the malleo-incudal body embedded in granulation tissue or the head of the malleus entirely lacking, in which case the handle appears to end abruptly above the processus brevis.

The manubrium seldom becomes carious as long as it is covered with the tissue of the membrana tympani. Only when the inflammation extends to its periosteum is a lacunar caries brought about, which eventually leads to absorption of the bone by the
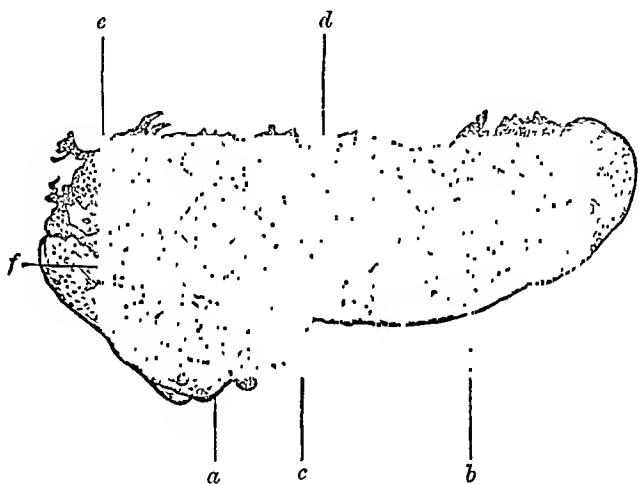
FIG. 238.—MICROSCOPIC SECTION OF THE CARIOUS ARTICULATION OF THE MALLEUS AND INCUS IN A WOMAN, THIRTY-TWO YEARS OLD, WHO DIED FROM AN ABSCESS IN THE CEREBELLUM, AND WHO HAD SUFFERED FROM OTORRHŒA SINCE CHILDHOOD.

a, Head of malleus; *b*, Body of the incus; *c*, Capsular ligament; *d*, Cavity of the joint opened by erosion of the capsular ligament; *e*, *f*, Enlarged osseous spaces filled with round cells.

formation of granulation tissue and giant cells (Moos). In many cases examined histologically by the author, the partial osseous defect, resulting from the suppuration, was filled with new-formed connective tissue.* As a rule, the inferior part of the handle is destroyed; it is rare to find the entire handle so completely affected that only a stump remains at the processus brevis.

The frequent occurrence of carious destruction of the free long process of the incus has been confirmed by many authors. That the loss of this process causes an interruption to the propagation of sound-waves between the tympanic membrane and the labyrinth, and thus produces a considerable disturbance of hearing, has already been mentioned. An ankylosis of the malleo-incudal

* Cp. *Atlas der Beleuchtungsbilder des Trommelfells*, p. 25.

articulation is not an infrequent sequela of chronic middle-ear suppuration (H. Frey).

The loss of the head and crura of the stapes through necrosis has been repeatedly observed; sometimes the necrosis of the crura of the stapes is so complete that only the foot-plate remains in the fenestra ovalis.

In a case of exhausted middle-ear suppuration, the author found the crura of the stapes partly destroyed, the stumps of which were covered with connective tissue. In another case—that of a woman twenty-one years of age who, in consequence of a right-sided chronic middle-ear suppuration, was
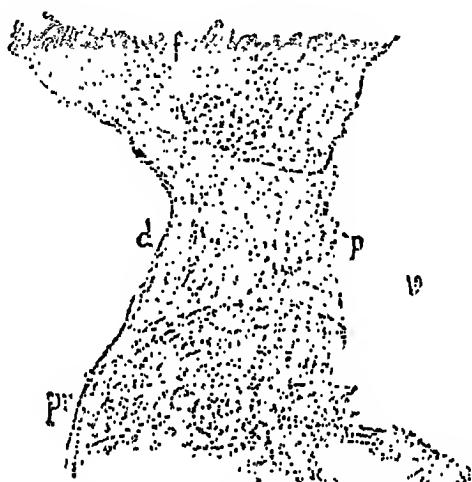
FIG. 239.—FRONTAL SECTION THROUGH THE RIGHT PELVIS OVALIS AFTER THE CESSATION OF A MIDDLE-EAR SUPPURATION.

f, Upper; pr, Lower wall of the niche; d, p, Newly-formed connective tissue filling the pelvis ovalis; d, Epidermal covering of the connective-tissue growth on the inner wall of the tympanic cavity; p, Base of the stapes perforated in several places.

entirely deaf since childhood—the author found on histological examination,[*] the recess of the fenestra vestibuli filled with new cystic connective tissue, the head and crura of the stapes entirely wanting, and the foot-plate perforated at several places by the connective tissue which had extended into the vestibule (Fig. 239).

One of the rarest occurrences is necrotic exfoliation of the entire malleus without caries of the walls of the tympanic cavity.

Softening of the ossicles has been observed by A. Hartmann and Bezold; this was probably due to a decalcification brought about by the purulent secretion.

In the course of suppurative processes in the middle ear there is sometimes a loosening and luxation of the ossicular joints,

* A. Politzer, *Recherches histologiques sur les changements pathologiques dans les niches de la fenêtre ovale*, etc. (Congrès de Bruxelles, 1889).

in consequence of absorption of the capsular ligaments or through pressure from granulations or cholesteatomatous masses. A dislocation of the incudo-stapedial articulation is the most common. It is a more rare occurrence to find the malleo-incudal articulation dislocated; when such is the case, however, the incus is either pushed into the mastoid antrum or expelled by the suppurative process.

The separation of the malleo-incudal articulation almost always causes a change in the position of the malleus. In such cases the malleus appears nearly turned on its axis, and is supported either by the tendon of the tensor tympani or, as in one of the author's cases, by the anterior ligament of the malleus, whereupon it appeared so turned on its axis that its head was directed outwards towards the lumen of the external meatus, and its handle inwards towards the attic.

It must be added that the connecting ligament between the foot-plate of the stapes and fenestra ovalis is often so loosened that the stapes falls out of its place, even if most gently touched with a probe. Nevertheless, the stapes is often still found intact in *post-mortem* examinations, when the membrana tympani, malleus, and incus are lacking.

The process of destruction is not always limited to the capsular ligaments of the ossicles; the ligaments and check-bands which connect the ossicles with the walls of the tympanic cavity, as well as the tendons of the intratympanic muscles, are also frequently involved in the process; this is most commonly met with in the scarlatinal-diphtheritic forms of middle-ear suppuration. As a result of this, one finds that one or all of the ossicles are either expelled spontaneously or are washed out of the meatus intact during syringing.

Diagnosis.—The diagnosis of caries of the ossicles can be made with certainty only if defects in the handle of the malleus are visible on inspection, and if, on probing through a perforation of Shrapnell's membrane or through a defect in the external attic wall, rough places are felt on the neck of the hammer or on the malleo-incudal body. It can positively be stated that the long process of the incus is destroyed if, in large defects reaching to the posterior superior periphery of the membrana tympani, the head of the stapes lies free and is not united with the above-mentioned process.

The diagnosis of caries and necrosis of the malleo-incudal body can be made with great probability from the following symptoms: Persistent suppuration with the formation of a fistulous opening in the posterior superior quadrant of the membrana tympani, the escape of septic or curdy secretion from the attic when examining with Siegle's speculum, and perforation of Shrapnell's membrane with the continued reappearance of granulations in the external attic.

The statement made by many authors that one could locate the seat of the caries in the ossicles by the position of the perforation is not always true; the author convinced himself of this by autopsies on a number of cases. A perforation of the posterior superior quadrant of the membrane reaching to Shrapnell's membrane ought to indicate caries of the long process of the incus; a perforation of Shrapnell's membrane anterior to the processus brevis, caries of the malleus; one behind the processus brevis, isolated caries of the incus (Grunert); and fistulous openings in the external attic wall, caries of the malleo-incudal body.

Caries of the ossicles may heal by · the formation of scar tissue. Often, however, it is the cause of a persistent suppuration of the middle ear which resists all local treatment. It also often prevents the outflow of pus or the discharge of a cholesteatomatous mass from the attic—a fact which has been confirmed by Goerke (*Archiv f. Ohrenheilk.*, vol. lii.), based on a series of cases examined histologically. When this is the case, it is an indication for the operative removal of the malleus and incus. Owing to the fact, however, that one can never tell with certainty whether the caries is limited to the ossicles, or, as is very often the case, combined with necrosis of the temporal bone, the absolute indications for extraction of the ossicles becomes considerably limited. Therefore we can never state in advance whether, after the extraction of the ossicles, the middle-ear suppuration will cease.

The method of extracting the malleus and incus which was first proposed by Schwartze (1873) and later by Kessel (1885) has, during the last few years, been further improved by Reinhard, Stacke, Grunert, Panse, Schubert, Ludewig, Wetzel, Stucky, Neumann, and others.

Indications.—The indications for the extraction of the malleus and incus may be grouped as follows:

1. Obstinate middle-ear suppurations which resist all local treatment and are associated with extensive destruction of the membrana tympani, and in which the malleus and incus are no longer of value in transmitting the waves of sound.

2. An obstructed flow of pus from the superior tympanic space (*cavum epitympanicum*). We must mention here the accumulations of cholesteatomata, and excessive formation of granulations in the attic, which always recur in spite of repeated removal.

3. Obstinate attic suppurations associated with perforation of Shrapnell's membrane, and with marked deafness. On the other hand, the author is opposed to the extraction of the ossicles in slight deafness associated with perforation of this membrane, as he has become convinced that in the overwhelming majority of cases this slight deafness is present when the suppuration is localized in the external attic. If, in these cases, there are no symptoms of complication, we can adhere to the conservative treatment; as a matter of fact, we are often compelled

to do this because the patient, who must be informed of the possibility of a change for the worse after the extraction of the malleus and incus, generally refuses to be operated upon. Should, however, alarming symptoms arise in such a case, one should not confine one's self to the extraction of the ossicles, but one should proceed immediately to the more radical procedure of a mastoid operation.

We must also add to the indications for extraction of the malleus and incus, with a simultaneous excision of the adherent or calcareous membrana tympani: Exhausted middle-ear suppurations with a high degree of deafness, in consequence of adhesion of the handle of the malleus to the promontory wall; flat adhesions of the membrana tympani and manubrium to the inner wall of the tympanic cavity; extensive, rigid calcification of the membrana tympani; demonstrable ankylosis of the malleus and incus; and permanent stenosis of the tube. The last-named indications, which are of importance on account of their influence on the improvement in hearing, require further clinical observations.

Operation.—The extraction of the ossicles is carried out by the intra-aural method. Gomperz and Neumann deserve the credit of having made this procedure possible through a method of local anæsthesia of the external auditory canal, which they introduced into practice.

In order to perform local anæsthesia, we use a syringe devised by Neumann, which is capable of holding ten minims of a 1 per cent. solution of cocaine or novocaine, to which 2–3 drops of adrenalin solution have been added. The needle is introduced about $\frac{1}{2}$ cm. external to the place of union of the cartilaginous and osseous meatus, and pushed forward under the periosteum, as far as the osseous meatus. A sign that the injection has been successful is evident by the vesicular bulging of the cutis at the place of injection, and by a bleaching of the skin of the canal and of the external layer of the drum.

It is only after complete anæsthesia has been obtained, which is generally a few minutes after the injection, that we may begin the operation.*

The operation is carried out as follows: The malleus is first incised on all sides with a small knife rounded at the end (see p. 322), and thereby freed completely from the remnant of the membrana tympani. If the end of the handle of the malleus is adherent to the promontory, it is detached with a small blunt hook, and pulled forward. The Delstanche ring-knife (Fig. 240), Fig. 240. which has an upper cutting edge, is then made to embrace the hammer and pushed up as high as possible, whereupon the tendon of the tensor tympani as well as the

* Cp. Milton J. Ballin, *New York Med. Journal*, 1906.

ligaments holding the hammer in place are severed. As a result of this, the hammer becomes so loosened that it can be grasped with a pair of forceps, pulled down towards the middle-ear cavity, and extracted.

Extraction by this method is usually very easy. In some cases it is rather difficult, especially when the malleus is fastened to the incus by adhesions and masses of connective tissue, or by firm ankylosis, in which case the manubrium breaks off at the neck and the head remains in the attic. This unfavourable mishap may also occur in caries of the neck of the hammer, or if a too rapid attempt at extraction is made, and one neglects to previously draw the malleus downwards into the middle of the tympanic cavity.

Extraction of the incus is much more difficult. Ludewig (*Archiv f. Ohrenheilk.*, vols. xxix. and xxx.) deserves the credit of first having proved that suppuration is rarely stopped through extraction of the carious hammer alone if the carious incus is allowed to remain in the tympanic cavity. Isolated caries of the incus is much more frequent than isolated caries of the hammer; this has been substantiated by Grunert (*A. f. O.*, vol. xxxiii.) and Schröder (*A f. O.*, vol. xlix.).

Considering that the therapeutic effect of the hammer extraction is not always successful owing to the fact that the carious incus is allowed to remain, it is always advisable, in order to be more certain of a cure, to remove both ossicles at one time.

For this purpose we use two small spoons (in two sizes), which are bent at a right angle at the end, one for the right ear, and one for the left ear (Fig. 241), instead of the incus-hooks of Ludewig or the eyelet-shaped instruments of Zeroni. Extraction of the incus is carried out in such a way that the small spoon is introduced into the space which was occupied by the hammer, and pushed up into the attic, whereupon it is pulled slightly forward, pressed against the internal surface of the external attic wall, and then turned backwards at an angle of 90°. In this way the incus is brought into the inferior tympanic space, where it can be removed with a pair of forceps.

Fig. 241.

After extraction of the hammer and incus, the attic is irrigated with an antiseptic solution by means of a Hartmann cannula, and the granulations and cholesteatomatous masses removed with small curettes bent at an angle (Fig. 224, p. 434). Inasmuch as the local anæsthesia lasts for some time, we can also remove the external attic wall in cases in which the examination with the curette shows the presence of extensive cholesteatomata in the upper tympanic space.

After extraction of the ossicles there is generally a profuse discharge, which, in cases running a favourable course, is easily arrested with irrigations of the attic with a Hartmann cannula.

Extraction of the malleus and incus brings about a lasting cure in only a small number of cases, as in the majority of cases the suppuration continues or soon recurs. If, therefore, the above-mentioned pathological changes are present, extraction of the malleus and incus is indicated only if there are no subjective or objective symptoms which necessitate the more radical procedure of a mastoid operation. It should be tried only as a last resort to stop an obstinate middle-ear suppuration running its course without symptoms, and should be undertaken, in the majority of cases, only as a preliminary operation to the radical opening up of the middle-ear spaces.

Extraction of the malleus and incus has, in the majority of cases, only a slight influence upon the hearing. There is seldom a change for the worse, and in some instances there is even a decided improvement.

Extraction of the Stapes.—Extraction of the stapes during the course of a middle-ear suppuration is absolutely contraindicated, as by this procedure the suppuration may extend to the labyrinth.

On the other hand, the author thinks that extraction of the stapes after an exhausted middle-ear suppuration is of value, and does in rare cases give a satisfactory result. Blake and Jack (*Transactions of the American Otological Society*, 1893) were of the same opinion. Blake suggested that extraction of the stapes should be carried out only after an unsuccessful attempt at mobilization or synechotomy. The following cases, observed at the author's clinic, show the favourable result that can be obtained by extraction of the stapes after an exhausted middle-ear suppuration.

In a case observed by the author—namely, that of a young girl in whom the region of the right fenestra ovalis was covered with a dry crust after a middle-ear suppuration had run its course—the stapes was accidentally extracted in 1897 by one of the assistants in his clinic while trying to remove the crust with the forceps. Immediately after its removal severe dizziness and vomiting occurred, which disappeared in a few days. After four days one could see a grayish-red membrane closing the fenestra vestibuli. The improvement in hearing which resulted in this case after the extraction of the stapes continued, and improved from 2 to 6 metres after the introduction of a pledget of cotton which was dipped in liquid vaseline, and advanced as far as the recess of the oval window. In a girl 20 years of age, there was hardness of hearing after a left-sided scarlatinal otitis, which she had in her twelfth year. *Status præsens :* Nearly a total destruction of the membrana tympani, tympanic cavity dry and of a tendon-gray colour, and the head of the stapes lying free. Speech heard at 30 cm.; Rinne negative. Schwabach lengthened. Extraction of the stapes with a small hook was carried out very easily. An improvement in the hearing to 6 metres for speech followed this

manipulation immediately. The opened fenestra ovalis was closed with a pledget of cotton soaked in paraffin, and the patient was made to lie on the right side, in order to prevent the escape of the labyrinthine fluid. On the fifth day after the operation the patient could walk about the room, but complained of a slight dizziness. On the ninth day the cotton pledget was removed, and the fenestra ovalis was overgrown with reddish tissue. Hearing distance, 3 metres. At an examination made several months later the fenestra ovalis was closed by a gray, shining, depressed cicatrix. Perception for speech was reduced to 2 metres. A membrane covering the fenestra cochleæ was severed with a small curved knife. An improvement in hearing up to 6 metres followed. Six months later it was 5 metres.

The Diseases of the Mastoid Process, with Special Reference to its Opening up by Operative Procedures.

A. Inflammation and Abscess Formation in the Mastoid Process during the Course of Acute Middle-Ear Suppurations.

Inflammation of the mastoid region occurring during the course of an acute middle-ear suppuration is brought about by the inflammatory process, extending by continuity from the tympanic cavity to the muco-periosteal lining of the mastoid cells.

The pneumatic mastoid process is more frequently affected by the inflammation than the diploëtic.

The author has proved by numerous *post-mortem* examinations that in every acute middle suppuration pus is found in the pneumatic cells of the mastoid process. The presence of pus in the mastoid antrum and cells does not in any way imply that an abscess has formed in the mastoid process. One can therefore speak of the formation of an abscess in the mastoid process only when, owing to bacterial infection, the lining membrane of the cells, and at the same time the osseous tissue, show symptoms of breaking down.

According to the author's view, an important cause of abscess formation is to be found in the anatomical construction of pneumatic mastoid processes. While, in many cases, there is an extensive communication between the antrum and mastoid cells, in others the opening is so narrow that only the smallest needle can be passed through. Occasionally the entire mastoid process consists of one or two large cavities, at the upper portion of which a canal, scarcely large enough for the passage of a bristle, is found communicating with the antrum. If these small openings between the antrum and mastoid cells become occluded by swelling of the lining membrane, and the pus cannot escape from the cell cavities, an inflammation of the osseous tissue is produced.

Symptoms.—The symptoms of acute inflammation of the mastoid cells vary considerably. In otitis media acuta running its course without perforation of the membrana tympani, symptoms of irritation in the mastoid process often arise, which usually subside spontaneously, or after a suitable antiphlogistic

treatment. In the acute, purulent middle-ear affections, symptoms of inflammation in the mastoid, such as pain and tenderness on pressure and percussion, develop more often before, than after perforation of the membrana tympani.

The reactive symptoms in the mastoid process accompanying acute, suppurative middle-ear inflammation may disappear after an appropriate antiphlogistic treatment, or spontaneously after repeated remissions and exacerbations. This is most frequently observed in the primary, acute middle-ear suppurations. On the other hand, abscess formation in the mastoid process is very much more frequent in influenza otitis, and in those forms of middle-ear suppuration occurring during the course of infectious diseases.

The acute abscesses in the mastoid have, with but few exceptions, their seat in the middle and lower parts of its vertical portion. They are more often situated in the superficial parts lying next to the cortical layer than in the deeper layers.

Generally only one abscess cavity is found; still, in the first few days of the disease there may be several, separated from one another by a considerable distance, which, during the further course of the infection, may unite. Small disseminated abscesses, from the size of a millet to that of a hemp seed, are usually found in diploëtic mastoid processes (ostitis of the mastoid process), and not infrequently also in the pneumatic mastoids in the beginning of the affection.

The symptoms of abscess in the mastoid process are:

1. Persistent or remittent pain in the mastoid, which is increased on pressure and percussion. The tender portion, however, does not always indicate the location of the abscess within the mastoid process. The parts most sensitive to pressure are the fovea mastoidea, the tip, and its posterior border corresponding to its terminal cells. In spite of extensive abscess formation, spontaneous pain and tenderness may be entirely wanting.

2. Temperature. This usually fluctuates from 99° to 102°–103° F., and may occasionally rise to 105° F. · It is usually unaccompanied by chills, unless there is some more severe or deep-seated complication. It not infrequently runs its course without any fever at all.

3. A marked increase in temperature on the mastoid as compared to the healthy side.

4. Œdematous swelling, or inflammatory infiltration and reddening of the integument covering the mastoid process. In the beginning of the inflammation, the swelling and diminished mobility of the skin can be recognized only by comparison with the other side. When the infiltration becomes more marked, the swelling on the mastoid process causes the auricle to stand away from the head. If the swelling on the mastoid appears in the

first few days of the disease, one may assume that the seat of the abscess is superficial. If, on the other hand, the swelling develops only after the middle-ear affection has existed for several days or weeks, one may take it for granted that an extensive absorption of the bone has taken place in the mastoid process. When rupture of the pus has taken place at the tip (Bezold mastoiditis), a hard, non-fluctuating swelling develops below the mastoid. Nevertheless, even in large abscesses, the skin covering the mastoid process is often, unaltered.

5. The membrana tympani appears strongly bulged forwards before rupture. After perforation has ensued, there is often found in the posterior superior quadrant of the membrane, a round or nipple-like projection (*vide* p. 352).

6. Bulging of the posterior superior wall of the meatus, with narrowing of the lumen of the auditory canal. Among the indications for opening the mastoid process, great importance must be attached to this symptom.

7. A profuse muco-purulent, or thick purulent, discharge from the ear; still, the discharge from the tympanic cavity may be slight or cease, while the inflammation in the mastoid process, which leads to the formation of an abscess, may continue uninterruptedly.

8. Facial and abducens paralysis, which may be reckoned to be rare complications of an acute mastoiditis.*

Course.—The symptoms of abscess formation in the mastoid process may continue several weeks, with remittent pains and with marked variations in the bodily temperature. A profuse discharge from the ear generally signifies a continuance and extension of the abscess formation, while a decrease in the discharge with a simultaneous diminution in the pain allows one to conclude that the inflammation is subsiding. Occasionally, however, cases are observed in which, after complete remission for several days, severe symptoms again arise suddenly which necessitate the immediate opening up of the mastoid process. On the other hand, experience has shown that an extensive abscess formation in the mastoid process may exist many months without any symptoms, and that the presence of such a condition can be assumed with great probability only from the obstinate continuance of the middle-ear suppuration.

A number of unusual cases observed at the author's clinic are examples of abscesses in the mastoid process which appeared a long time after the cessation of an acute middle-ear suppuration; in fact, in these cases, the symptoms of abscess formation became evident when the perforation in the membrana tympani had closed, and when the hearing had again returned almost to normal. This form of acute mastoiditis is most frequently

* Cp. Alt, *Monat. für Ohrenheilk.*, 1906

caused, according to Neumann and Ruttin, by the *Streptococcus mucosus*. The disease in the mastoid process seldom develops with severe pain, tenderness on pressure, and fever, and more often entirely without any reaction. It is characterized by an œdematous or hard swelling on the mastoid process, with symptoms of a periostitis mastoidea, which goes on to the formation of a periosteal abscess. If one fails to open the mastoid at this stage, the inflammation extends from here to the tympanic cavity, and the membrana tympani becomes injected, swollen, protrudes, and finally perforates. If, in such cases, the mastoid process is opened, one finds a diseased cavity which may or may not be in communication with the antrum, and which is filled with unhealthy granulations. A cure is almost always obtained by thoroughly curetting the mastoid process and making a free opening into the antrum.

Terminations.—The terminations of acute ostitis of the mastoid are: (1) Recovery after the disappearance of the inflammatory changes in the mucous membrane. (2) Abscess formation. (3) Softening, absorption, and cario-necrotic destruction of the bone. The osseous tissue is softened, and the abscess cavity is filled partly with pus and partly with unhealthy fungoid granulations, in which fragments of necrotic bone from the walls of the pneumatic cells, or a rather large sequestrum, are embedded. These changes are usually found after the abscess has existed for a long time, and in the otitis arising in the course of the infectious diseases. (4) Spontaneous perforation of the abscess through the external cortical layer resulting in a large post-auricular fluctuating swelling. This is very frequently seen in children, and takes place by way of the sutura squamo-mastoidea, or through the formation of a fistula in planum mastoideum. The abscess, in rare cases, perforates the posterior wall of the meatus or the medial surface of the mastoid process (Bezold), whereupon the pus sinks down along the inter-muscular spaces in the side of the neck or along the anterior surface of the spinal column, and spreads out in the mediastinum (see p. 473).* (5) Extension of the suppuration from the mastoid process to the cranial cavity, producing extradural abscess, pachymeningitis interna, leptomeningitis, and brain abscess, or to the sigmoid sinus, causing a sinus phlebitis and thrombosis, which may or may not end fatally.†

That a mastoid abscess may heal without spontaneous perforation and without the operative opening of the mastoid is beyond doubt; this has been proved time and time again by clinical observation and by the condition of the abscess cavity when the mastoid was opened. The author has repeatedly

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* Bezold's mastoiditis will be discussed in the following chapter under Intercurrent Acute Mastoiditis.

† Dem. Demetriades, *The Suppurative Middle-Ear Inflammations and their Sequelæ* (Greek). *Habilitationschrift, Athen*, 1895.

seen recovery take place in patients who had marked symptoms of an abscess and who refused the operative opening of the mastoid process. Still more convincing proof that an abscess may heal spontaneously is afforded by those cases in which, after a middle-ear suppuration has existed many weeks, we decide to open up the mastoid process on account of tenderness on pressure and the profuse otorrhœa; in such cases one sometimes finds, especially in the primary forms of otitis, the greater part of the mastoid filled with healthy granulations without the presence of pus, and the osseous septa absorbed. From these observations one gets the impression that a cure might have taken place without an operative procedure through the filling up of the abscess cavity with granulation tissue which has a tendency to ossify.

Diagnosis.—The diagnosis of abscess formation in the mastoid process is made from the symptoms previously described, and from the course of the disease. It is most difficult at the beginning of the affection, as the pain and tenderness over the mastoid in acute middle-ear suppuration, which may be temporary, or even remain for some time, may be produced merely by the marked swelling of the lining of the mastoid cells and congestion of the osseous tissue. On the other hand, the diagnosis of an abscess is almost certain if pain in the mastoid (with or without swelling of its integument), persistent fever, sleeplessness, nervous excitement, profuse otorrhœa, and narrowing of the meatus continue longer than eight days. If the patient comes under observation with these symptoms after the otitis has lasted several weeks, there can be no doubt as to the presence of a mastoid abscess.

Percussion of the mastoid process with a small metal hammer or with the finger-tip is regarded by Körner, Wilde (*Z. f. O.*), 1892), and Eulenstein as an important aid to diagnosis. In cases of unilateral mastoiditis, when the process is entirely made up of pneumatic cells, comparative percussion often yields a short and hollow sound on the diseased side. One often finds, however, in spite of an empyema which is made evident by the operation, no difference in the percussion sound between the healthy and diseased mastoid. In spite of all this, when a positive result is obtained by percussion, it is always to be regarded of diagnostic value only if taken in connection with other symptoms of mastoid abscess; this is especially true if dulness develops while the patient is under observation.*

Prognosis.—The prognosis of acute mastoiditis is, on the whole, more favourable in the primary forms of otitis than in the middle-ear suppurations due to influenza, typhoid fever, to the scarlatinal-diphtheritic and tuberculous processes, diabetes, and syphilis. The virulence of the infection exercises an important influence on the prognosis. When an abscess forms, the prognosis is materially influenced by early therapeutic measures. Abscesses which have existed a short time, and are not very extensive, heal more rapidly after opening up, than those that have existed for several weeks, and in which a large portion of the mastoid cells has been destroyed.

* Cp. Moos, *Z. f. O.*, 1893; Körner, *Die eitrigen Entzündungen des Schläfebeins*, 1899. Barth, *A. f. O.*, vol. xlvii.

Treatment.—The treatment of acute mastoiditis depends on the stage in which the patient comes under observation. If one has the opportunity of observing the patient during the first few days of the disease, before perforation of the membrana tympani has taken place, the membrane appears strongly congested, swollen, and bulged outwards; if there is, at the same time, spontaneous pain in the mastoid (mastoid tenderness), which is increased on pressure, our first step is to perform paracentesis in order to give the pus, which has collected in the middle ear, an opportunity to escape. This operation, the simple technique of which every practitioner should acquire, is sometimes sufficient to cause the inflammatory symptoms in the mastoid to subside. Small perforations must be enlarged with the paracentesis knife, and nipple-shaped projections must be incised. In addition, the inflammation in the mastoid should be combated during the first few days by an energetic, antiphlogistic treatment; this is best accomplished with the application of a small Sprague ice bag. In using the ice bag one should not apply it over the mastoid continuously. It is advisable to apply it for half an hour, and then to leave it off for an hour. By using it in this way one avoids a painful dermatitis, which sometimes develops as a result of the cold. The application of various medicaments over the mastoid has proved of no value. The continued use of the ice is also not advantageous, as it often causes a redness of the skin and pain, which may mask the true mastoid pain and may be misleading.

By the treatment just described it is often possible, especially in the primary forms, to alleviate the symptoms of inflammation in the mastoid after three to eight days, and to notice a marked improvement in the aural condition. The tenderness gradually subsides, the discharge becomes less copious, and the temperature gradually comes down. In a large number of cases this mode of treatment does certainly abort the inflammatory process in the mastoid cells, and prevent the formation of a true mastoid abscess necessitating operative interference. Antiphlogistic treatment proves less efficient in inflammations of the mastoid cells produced by influenza, diphtheria, scarlet fever, tuberculosis, and syphilis. In an otitis due to these diseases it is seldom possible to check the formation of an abscess in the mastoid process by the conservative treatment; in the majority of these cases it is necessary to open the abscess from the mastoid process.

The hyperæmic treatment, which was introduced by Bier (*Archiv f. Klin. Chir.*, vol. lxvii., p. 164), and which proved a valuable method in surgical practice, has also been recommended for acute otitis and mastoiditis. Bier uses an elastic bandage, 3 cm. in width, which he allows the patient to wear around the neck for at least ten, but as a rule twenty to twenty-

two, hours.　Owing to the pressure on the bloodvessels of the neck, there is produced a stasis of the vessels in the entire head and also in the ears.　Bier is supposed to have obtained favourable results in a number of cases treated with his method.　This form of treatment has not found much favour amongst otologists, and is rarely used.

Eschweiler (*Archiv f Ohrenheilk.*, vol. lxxi.) has, at the clinic in Bonn, obtained such favourable results with Bier's treatment in acute mastoiditis that he is of the opinion that this hyperæmic treatment is bound to reduce operative procedures.

According to Kepler (*Zeitschr. f. Ohrenheilk.*, vol. l.), who recommends it in acute cases, the stasis exercises an alleviating influence on the pains.

The reports of Heine (*Verh. d. deutschen otol. Ges.*, 1905) are less favourable.　According to him, the pains are not particularly benefited, but even increased at times.　He could get a few good results in mastoiditis with infiltration of the soft parts.　Heine thinks that this method is not advantageous, because the proper moment when to operate is overlooked, owing to a masking of the symptoms as a result of this stasis.

Stenger, Hasslauer and Körner are more or less opposed to this method. Isemer, at Schwartze's clinic, is decidedly opposed to the Bier treatment. He regards its long application in acute cases as decidedly harmful.

Fröse (*Archiv f. Ohrenheilk.*, vol. lxxi.) draws attention to the anatomical conditions in the mastoid which are unfavourable for Bier's method.　From his experience at the clinic in Halle, he warns in particular against its use in severe infections of the middle ear and of the mastoid process, and in tuberculosis.　He thinks it may be used only in the mild, uncomplicated, and in the subacute otitis running its course with mastoiditis. Chronic uncomplicated suppurations seem to be favourably influenced.

Owing to the various results obtained by this method of treatment, it is impossible to give a positive opinion as to the value of Bier's hyperæmic method in cases of otitis and mastoiditis.　Inasmuch as the success of the method depends upon the nature and duration of the aural affection, and upon the degree and length of time the stasis in the head is kept up, further observations in selected cases are still necessary to establish the indications for its use.

During the last few years the suction treatment in acute middle-ear suppuration, as recommended by Sendermann (*Archiv f. Ohrenheilk.*, vol, xlvi.), has found many advocates.　By this method the purulent secretion is aspirated from the middle ear, thereby cleansing the tympanic cavity more thoroughly, reducing the inflammatory condition, and shortening the time of treatment. That the suction has little effect on the abscess in the mastoid is readily appreciated, because the abscess cavity hardly ever communicates directly with the antrum.　Aspiration after paracentesis in middle-ear suppurations, in order to remove the purulent secretion from the antrum and attic, combined with an inflation of air, has been used for many years.　For this purpose Siegle's speculum or the electrically driven suction apparatus is most useful.

The Indications for Opening the Mastoid Process.

The mastoid process must be opened immediately if the antiphlogistic treatment is of no avail after several days' application; if the profuse otorrhœa, pain in the mastoid, and fever continue; and if symptoms of a labyrinthine or meningeal irritation (vomiting, dizziness, disturbance in equilibrium, nystagmus) or chills

develop.*   The immediate operation is also indicated if, with the profuse otorrhœa, symptoms indicative of abscess formation have lasted for more than ten days.

The cases in which recovery takes place without operative interference would seem to afford arguments for delay.   If, however, we bear in mind that every mastoid abscess, when allowed to exist a long time, leads to extensive destruction of the bone, and that by waiting too long we may be surprised by a sudden, fatal, intracranial complication, it is evident that an early operative interference is advisable, especially as the operation is comparatively free from danger.†

Early opening of the mastoid has the advantage that the abscess is still small, and that by scraping out the diseased tissue the loss of substance in the bone is not as extensive as when the abscess has existed a long time; furthermore, that the process heals more rapidly, and that the middle-ear affection runs its course more quickly.   A shortening of the time of treatment is also of value, as the hearing function is less likely to become impaired.

The experience of the last few years has, however, convinced the author that in many cases the too early opening of the mastoid process—that is, already on the fourth or fifth day—has an unfavourable effect on the course of the disease and on the process of healing.   One finds, especially in those pneumatic mastoids composed of small cells which are opened during the first eight days of the disease, several disseminated collections of pus spreading in all directions, instead of one abscess cavity. In such cases the wound heals badly—in fact, much worse than if one abscess cavity were found—as it is seldom possible to remove all the diseased bone substance.   As a rule, therefore, the author rarely operates before the eighth day of the disease, and thinks that one should operate before this time only when, in addition to an early swelling and redness over the mastoid process, symptoms of meningeal irritation or chills appear.   It should be emphatically stated that the conservative treatment should in all cases have a fair trial, as one finds in nearly every case of acute purulent otitis media a more or less sensitiveness in the mastoid process, which invariably disappears within a short time.   If we keep in mind the anatomical structure of the middle ear, we find that the lining mucous membrane is the same as that which lines the mastoid cells, so that any inflammatory condition in the tympanic cavity is conveyed by continuity to the mastoid process.   This produces a hyperæmia with increased exudation, ·

* According to Stenger (*Archiv f. Ohrenheilk.*, vol. lxii.), a simultaneous swelling of the lymph glands in the mastoid process must also be counted amongst the indications for operation.   An optic neuritis, according to Barnick, makes the opening up of the mastoid imperative.

† Jos. Pollak, *Diagnostik und Therapie der akuten Mittelohrentzündungen und ker konsekutiven Ostitis mastoid. Zentralblatt f. d. ges. Therapie*, 1896.

causing an increased intracellular tension with more or less pain on pressure. By means of the conservative treatment—that is, by hot irrigations and cold to the mastoid region, in addition to a free incision in the drum—the process is, in the majority of cases, arrested, so that these acute symptoms disappear, making operative interference unnecessary.

An urgent, vital indication for opening the mastoid process in acute middle-ear suppurations lies in the dangerous complications which the abscess may bring about.

There are two operations for opening a mastoid abscess: (1) The simple opening of the abscess, with the scraping out of the softened osseous tissue; and (2) the opening of the mastoid process and at the same time the antrum. Which of these two methods should be chosen in a given case can be decided only by the clinical symptoms, and by the conditions found at the time of operation. According to the author's experience, in the great majority of cases of acute mastoid abscess, especially in the primary forms of otitis, when no complicating symptoms are present, the simple opening of the mastoid, without the simultaneous opening of the antrum, brings about a much more rapid cure of the middle-ear affection than if the combined operation is performed, provided that there is a thick, resistant bony wall separating the abscess cavity from the antrum.

Opening the antrum is indicated in most cases, especially if there are symptoms of pus retention, labyrinthine symptoms (dizziness, nystagmus), or symptoms of meningeal irritation; furthermore, when there are nipple-shaped protrusions on the membrana tympani, and in cases in which the bony tissue separating the antrum from the mastoid is found decayed and soft during the operation, or when granulations grow from the abscess cavity into the antrum. Free opening up of the antrum brings about a more rapid cessation of the purulent discharge from the middle ear, and gives a better chance of preserving the hearing function.

Röntgen examination affords us a means by which we can at times determine before the operation whether we are dealing with a pneumatic or diploëtic mastoid process. In the great majority of cases, the X ray is of little value in determining the presence of an abscess formation in the mastoid process, and we should not place too much reliance upon it. The clinical findings should always be the determining factors in mastoid surgery, using the Röntgen plates, in some cases merely as a corroborative evidence. The abnormal position of the sigmoid sinus which is found at the operation cannot be determined beforehand. As a rule, a small, short, mastoid process generally indicates one of a diploëtic structure, while a large mastoid points to one of a pneumatic nature; still, exceptions to this rule not infrequently occur.* Of practical significance is the fact, first established by the author, that the abnormal location of the sigmoid sinus, forwards and outwards, is most

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* Stanculéanu et Depoutre, *Études anatomiques et pathologiques des groupes cellulaires postérieurs de la mastoïde. Ann. d. mal. de l'oreille*, 1901.

frequently observed in diploëtic mastoids, and less often in the pneumatic variety. As a rule, therefore, the conditions for operating on pneumatic mastoid processes are, on the whole, far more favourable, and one should always proceed cautiously when, during the course of the operation, the bone is seen to be diploëtic.

The Simple Mastoid Operation.

Instruments.—The instruments used in the mastoid operation consist of the following: Scalpels, artery forceps, a sharp and blunt periosteal elevator, a self-retaining speculum to keep the edges of the wound well apart, several anatomical and mouse-toothed forceps, a series of sharp gouges or chisels, a number of sharp spoons or curettes varying in sizes, several bone forceps or ronges also of different sizes and built at various angles, grooved directors, probes, etc. In place of sutures one may use the clamps of Michel for closing up the external wound. Other instruments may be added to suit each individual surgeon.

The instruments should be thoroughly sterilized, and the most rigid aseptic precautions must be observed by the operator and his assistants.

In preparing the patient for operation, the region around the mastoid must be shaved, and the hair thoroughly removed over a fairly wide area in order to make a large field for operation. This is then cleansed with alcohol, dried, and tincture of iodine applied to the entire external region of the ear and external canal. The iodine is then washed off again with alcohol, whereupon the head, neck, and body of the patient are draped with sterile sheets, towels, etc., leaving a well-exposed field for operation.

In the majority of cases, general anæsthesia is employed.

During the last few years the operation was performed, in a large number of cases, at the author's clinic under local anæsthesia with Schleich infiltration (Alexander),* or under local anæsthesia as proposed by Neumann (p. 487); this was done, not only in persons having a heart or lung affection, etc., and in whom a general anæsthetic was out of the question, but also in robust individuals who decided to be operated upon under local anæsthesia in order to avoid the unpleasant after-effects of a general anæsthetic. The method is as follows: About 10 c.c. of a 1 per cent. solution of cocaine, to which a few drops of adrenalin solution have been added, or a solution of novocaine, are injected subperiosteally at the planum mastoideum, and at the centre and tip of the mastoid process. In addition to these, 2 c.c. more are injected subperiosteally into the posterior wall of the external meatus, in that we introduce the needle directly behind the place of attachment of the auricle, and push it under the periosteum up to the region of the antrum. The anæsthesia, if

* *Wiener Klin. Wochenschrift*, 1901.

the technic has been carried out correctly, is without a fault. Local anæsthesia does not work well with subperiosteal abscesses.

The Operation.—While the assistant who stands behind the head of the patient bends the auricle somewhat forwards, the surgeon makes an incision 4–5 cm. in length and ½ cm. behind the insertion of the pinna; this incision, which is curved backwards, is begun immediately below the linea temporalis, and is continued downwards to almost the tip of the mastoid. The incision is made down to the periosteum, which is pushed back with a sharp periosteal elevator, exposing the cortical layer of the mastoid bone. When operating on the right ear, the author makes his incision from above, down; on the left ear, he finds it more convenient to cut from below, up. The hæmorrhage is easily arrested with artery clamps or with forceps, which are allowed to remain in place until the operation has been completed. Only large, spurting arteries require ligation. As a rule, parenchymatous hæmorrhages cease after the introduction of the self-retaining retractor.

The planum mastoideum between the spina supra-meatum and the apex of the mastoid process having been exposed, the cortex is chiselled away with a large gouge.* When operating upon the right mastoid, it is advisable to make several grooves with the chisel from the tip upwards towards the supra-meatal spine; while, on the other hand, when operating upon the left mastoid, one should begin from above and cut several grooves downwards towards the tip. Frequently the abscess is reached after the first blow with the hammer, whereupon the pus, which is under high pressure, escapes rapidly. Now and then the pus in the abscess cavity pulsates, which indicates that the dura or lateral sinus has been exposed through the suppurative process in the middle ear. In some cases, the abscesses are not found until a depth of ½ cm. or more is reached.

When the abscess cavity is laid bare, the opening in the bone is enlarged with the chisel or with the forceps in all directions. When the opening has been sufficiently enlarged, the abscess contents, which is comprised of granulations and softened bone, is thoroughly cleaned out with sharp spoons and curettes, and the walls of the cavity scraped down to the healthy bone.† With some experience one can easily differentiate the diseased tissue from the normal, in that the former gives way easily to the sharp spoon, while the latter offers a certain resistance. When an extensive abscess has existed a long time, it is occasionally necessary to take away the greater portion of the mastoid process,

* Opening the mastoid process with a burr is performed by only a few surgeons. Macewen of Glasgow, to whom we are indebted for the masterly manner in which he has developed brain surgery, uses for his mastoid operations knob-shaped burrs of different sizes.

† Morpurgo, *Wiener med. Wochenschr.*, 1887, No. 16.

so that one not infrequently comes upon the sigmoid sinus, a large extent of which has been laid bare by the suppurative process. Great care must be exercised in curetting the abscess cavity posteriorly in order to avoid wounding the sinus. In some cases it is even necessary to resect the entire tip of the mastoid process, whereupon one must be careful that one does not injure the facial nerve at its place of exit at the stylo-mastoid foramen.

The continuous, copious hæmorrhage which occurs during the scraping out of the abscess cavity arises either from the granulations, from the diploëtic tissue surrounding the pneumatic cell spaces, or from a large emissary vein of Santorini passing through
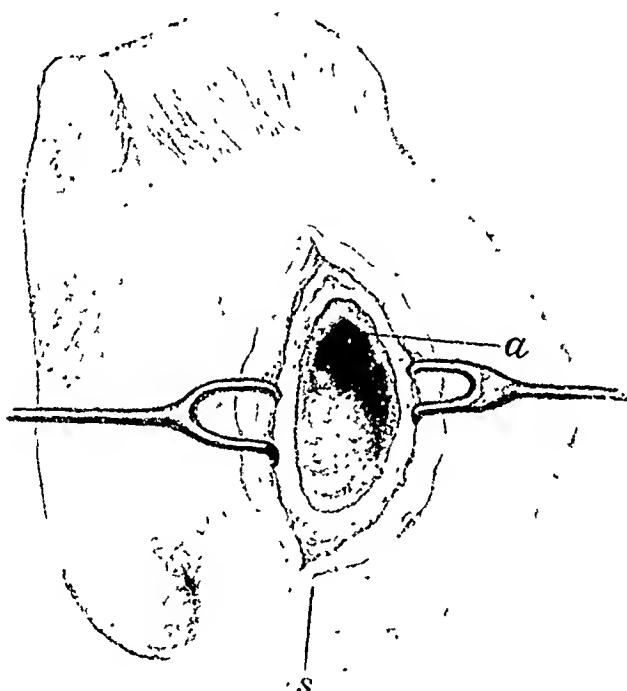
FIG. 242.

the mastoid process. It is usually possible to stop the hæmorrhage by repeatedly sponging the cavity with sterilized gauze, with or without the use of peroxide or adrenalin solution. When there is a sudden marked gush of blood from the bottom of the cavity, which cannot be readily arrested by tamponing, one can be rather certain that it comes from the sinus which has been accidently injured. In such cases we must pack the wound quickly and firmly.

If one is convinced that the abscess cavity has been thoroughly curetted and a free open communication established into the middle ear by way of the antrum, the cavity is cleansed with peroxide and alcohol. The writer then applies tincture of

iodine to the entire abscess cavity, which is again removed with alcohol. The wound is then packed with iodoform or sterile gauze. The writer never uses iodoform gauze owing to its toxic action, and particularly so in children. In order to make the wound somewhat smaller, several sutures or Michel's clamps are placed in its superior extremity. Complete closure of the wound immediately after the operation has proved unsatisfactory. Piffl. recommends immediate closure of the wound, with drainage at its lower extremity. This method has found favour with some surgeons, but is a rather risky procedure, as one can never tell whether there is not some necrotic tissue or pus pocket still in the wound cavity, making healing uncertain. In some cases it works very well, so that the results from a cosmetic as well as from a curative standpoint are very satisfactory.

The operative procedure described here is also used in the Bezold mastoiditis (rupture of the abscess on the medial side of the mastoid process), which will be discussed later on. When there is a sinking abscess on the side of the neck, it is necessary to remove the apex of the mastoid and eventually to open up the abscess in the neck by carefully dissecting away the muscles, fascia, and bloodvessels.

The Application of the Bandage.—After the abscess cavity has been tamponed and a strip of gauze has been introduced into the meatus, the mastoid process is covered with several layers of sterilized gauze. In order to make the gauze fit more closely at the posterior insertion of the auricle, the dressing is cut out to assume the shape of a crescent. The whole external region of the ear (auricle and mastoid process) is now covered with a layer of sterilized, absorbent cotton, and the entire dressing fixed by the application of a bandage. To keep the bandage in place the writer uses strips of adhesive plaster, which are applied at right angles to the bandage at several places. The bandage is applied in such a manner that the ear operated upon is completely covered, while the other remains free.

If the wound is running a regular course, the dressing is allowed to remain untouched for four or five days.

After the operation the patient should be confined to his bed for several days. His stay in bed is more protracted in those cases in which the dura or sinus has been exposed, or in which the wound is running an irregular course, and is accompanied by fever or pain. The bandage is usually changed on the fifth or sixth day, and sooner only in those cases in which marked pain or high fever continue, or when the bandage becomes soaked through with secretion after one or two days. If the wound is running a normal course and the bandage is allowed to remain too long, the granulation tissue occasionally grows into the gauze, which may occasion pain and hæmorrhage when the dressing is removed. In reference to the after-treatment, the author refers the reader to p. 505.

The favourable effect of opening the mastoid process is, in most cases, noticed a short time after the operation by a rapid

decrease in the fever, by a disappearance of the local pain, and by the subjective feeling of well-being on the part of the patient. Opening the abscess has also a remarkably good effect on the suppuration in the tympanic cavity, in that one finds that after a few days the discharge from the ear diminishes, and completely ceases within a week or ten days, with the formation of a cicatrix in the perforated membrana tympani.

The course is less favourable in the disseminated abscesses of osteomyelitis in diploëtic mastoid processes. In such cases the high fever, associated with occasional rigors, may continue a long time, and metastases may even develop in the joints, in the subcutaneous connective tissue, in the subperitoneal space, etc., which may eventually end in death. Nevertheless, the author has repeatedly seen recovery take place in complications of this kind.

The average time of treating the wound until complete cicatrization has taken place varies, if the course is normal, from four to six weeks. During this period, by the growth of healthy granulation tissue from all sides, the cavity of the wound gradually becomes smaller, and is finally filled up. The external wound heals either by the formation of a linear, cutaneous scar or by a more or less depressed osseous scar, to which the skin is closely adherent. The wound shows a very tedious course after scarlatinal diphtheria. The course is very irregular in middle-ear suppurations due to the acute infectious diseases, in influenza, tuberculosis, diabetes, and in cachectic individuals.

Unfavourable symptoms during the after-treatment are: (1) A profuse secretion of pus in the cavity of the wound, which in a short time soaks through the bandage. In these cases, the suppuration may be caused either by carious bone which has not been thoroughly removed, or by a purulent cavity in some other part of the bone which was difficult to reach. In order to ascertain the seat of such collections of pus the author proceeds as follows: If the purulent cavity cannot be discovered with the probe, and is, at the same time, not far distant from the surface of the wound, he uses a pneumatic speculum furnished with a large cup which fits over the outer circumference of the wound; by the aid of this it is possible to locate the seat of suppuration during aspiration by the appearance of a drop of pus in the wound, and then to lay it open.* Very often careful probing of the wound leads to the discovery of cario-necrotic parts of bone, which must be removed by scraping before recovery can take place. (2) Frequent rises in temperature and the occurrence of rigors. Slight fever (33°–38·5° C.=100°–101° F.), which is present before the operation, not infrequently returns for several days after the operation without having an unfavourable influence on the further course of the wound. On the other hand, continuous high fluctuating temperatures ranging from 99° to

* Also suggested by Hammerschlag as a therapeutic measure.

104° or 105° F., with or without rigors, give one good cause to suspect the presence of a perisinous abscess or a sinus thrombosis, and indicate a blood culture and the eventual exposure of the sigmoid sinus. (3) The appearance of headache, vomiting, dizziness, nystagmus, and a continuous subnormal temperature. These complications lead one to suspect the development of a labyrinthine suppuration or an intracranial complication, extradural abscess, meningitis, or brain abscess, which necessitate the exposure of that part of the dura mater above the antrum and tegmen tympani, and eventually the exploration of the brain for an abscess. (See the operative procedures in chapter on Intracranial Complications, p. 567.) (4) Erysipelas. This may develop without any known cause, or may be traced to infection due to a careless treatment of the wound.

Acute mastoiditis may have a fatal ending in consequence of *intracranial complications or diabetic coma.* Death is most frequently caused by the pyæmia associated with sinus phlebitis, brain abscess, extradural abscess, and in some rare cases by a leptomeningitis arising after a labyrinthine suppuration. A full description of these complications will show that even in such cases operative procedures not infrequently save the life of the patient.

Wilde's incision, which was formerly performed in acute mastoiditis, is now seldom used.*

Exposure of the sigmoid sinus during the mastoid operation, due to the fact that it is placed far forward and is abnormally curved outwards, is a very common occurrence. It is recognized on the internal and posterior wall of the abscess cavity by its bluishgray colour. This contingency, which was formerly looked upon with a certain dread, is no longer feared, as infection rarely takes place if its wall has not been injured during the operation, and if it has a normal appearance. On the contrary, one often exposes the sinus intentionally, in cases in which there is a high fluctuating temperature associated with chills, in order to see whether we have to deal with a perisinous abscess or a true sinus thrombosis.

Injuring the sinus during the operation is, on the other hand, a very unpleasant occurrence, and can generally be avoided if our operative procedures are performed with skill and care. Such an accidental rupture of the sinus is usually brought about by the careless use of the sharp spoon or chisel, and by being torn by a sharp spicule of bone. This accident, which in itself is not dangerous, is unpleasant, as it often necessitates our interrupting the operation owing to the uncontrollable hæmorrhage which usually ensues. In most cases the gush of blood can be arrested by firmly packing the wound, allowing the surgeon to finish the operation. In other cases, the bleeding is so severe that

* M. Lermoyez, *Traitement consécutif aux opérations faites sur l'oreille.* *Ann. d. malad. de l'oreille*, vol. xxix.

the operation must be discontinued for the time being and resumed at another time. Of course, one must not forget that such an accidental opening of the sinus allows infection to take place more readily, and affords a greater opportunity for the development of a sinus phlebitis. If the cavity has been firmly packed and the bleeding has been arrested, and if no untoward symptoms arise during the next few days, the packing is allowed to remain untouched for five or six days, at the end of which time the tear in the sinus wall is sufficiently healed to allow the wound to be redressed without any great danger. If bleeding should recur, the tampon must be quickly replaced.

Opening the middle cranial fossa and exposure of the dura mater are indicated if violent headaches and meningeal symptoms lead us to suspect an extradural collection of pus in the middle cranial fossa. The unintentional exposure of the dura mater is, in itself, just as devoid of danger as the exposure of the sigmoid sinus.

Injuries to the dura by splinters of bone or by the careless use of the curette or chisel are of greater importance, owing to the fact that they create a path of infection, which may ultimately lead to some cerebral complication or to a traumatic meningitis. If the dura is injured, it is recommended, acccording to Neumann, to enlarge the incision somewhat, whereby the development of a traumatic meningitis is most readily avoided.

The good effect of opening the mastoid antrum, which should be done in every case of acute mastoiditis, often becomes evident by the rapid subsidence of the violent pains, by a fall in the temperature, and by the disappearance of the dangerous symptoms. In nearly every case the middle-ear suppuration rapidly subsides after the operation. Not infrequently, however, the suppuration lasts for some time unabated, in spite of careful after-treatment, owing to a diseased condition of the walls of the tympanum or of the ossicles. In such cases it is sometimes necessary to resort to more extensive operative measures, in that we must, at a later date, perform a true radical mastoid operation.

After-Treatment.—If the wound is taking a normal course, the dressing need be changed only every three to four days. If the gauze is not wet through, and if pus is not seen on the surface of the wound, the cavity is again packed dry and loosely with iodoform or sterile gauze. The rapid growth of granulations on the surface of the wound is prevented if the cavity is packed too tightly.

If the bandage becomes wet through in a short time, owing to the oozing of blood or pus, or if the pains return, the bandage must be changed daily; if the discharge continues, irrigations with a 2 per cent. lysol or a 1 per cent. saline solution, or cleansing the cavity with peroxide solution, may be necessary.

In those cases in which the antrum has been opened, care must be taken to keep the communication between the tympanic cavity and the abscess cavity open as long as the suppuration in the tympanum continues. For this reason the rapidly proliferating granulations in the canal leading to the antrum, must be removed from time to time. Only when the suppuration in the tympanic cavity has ceased and the perforation in the membrana tympani has cicatrized may the antrum be allowed to close. Spongy granulations growing on the edges of the external wound, and thereby closing the entrance to the cavity, must be removed by means of a sharp spoon or with a pair of scissors, having first cocainized the parts. That the local treatment of the external and middle ears must go hand-in-hand with the treatment of the wound goes without saying.

The process of healing after the operation is sometimes rapid and sometimes slow. This depends principally on the local changes in the mastoid process, on the complications that exist within the tympanic cavity and in the external meatus, and on the state of the general health of the individual. Under favourable conditions the suppuration in the tympanic cavity ceases very quickly, and the wound fills so rapidly with granulation tissue that the normal cavity and the external opening close within two to six weeks. After scarlatinal diphtheria the process of healing is very slow, and the growth of granulations proceeds very sluggishly; sometimes, only after months, grayish-yellow, necrotic islands of bone within the granulating surfaces are noticed, which, after the application of lunar caustic ointment (1:10), or after painting with tincture of iodine, are cast off.

To close the wound quickly and to shorten the time of healing, the author[*] has proposed a method which consists in filling the cavity which has become completely lined with healthy granulations, with melted, sterilized paraffin (having first cleansed the cavity with diluted peroxide), and then immediately closing it up with sutures or Michel's clamps. This method is especially applicable in those cases in which the mastoid was scraped without opening the antrum. The patients operated upon at the author's clinic could follow their occupations within a few days after closure of the wound. Reactive inflammation after closure with paraffin was not observed. Röpke and Reinhard (Köln), who also used this method when opening the antrum, report favourable results. Hölscher[†] has recently also tried it in very large operative cavities in the mastoid, in which the sinus and dura were extensively exposed, and obtained good results.

Filling the cavity with glutol (Kretschmann) and with the Mosetig bone filling (Biehl), have not found many advocates. C. J. Blake (*Transactions of the American Otolog. Society*, 1898 and 1899), based on the favourable results which he has obtained, recommends that the cavity which has been thoroughly scraped out, should be filled up with the blood arising from the wound, and that the wound should be closed with sutures over the moist clot. By this operative procedure the formation of granulations is supposed to take place without reaction, and the time of treatment is supposed to be

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[*] *Wiener med. Wochenschr.*, 1903.					[†] *Zeitschr. f. Ohrenheilk.*, vol. xlviii.

considerably shortened. This method, which has found many adherents in America (Sprague,* Reik†), and which is also praised by Piffl, can give a favourable result only when all the diseased tissue has been thoroughly removed.

During the last few years various methods have been suggested to bring about a more rapid healing of the post-operative wound, and at the same time to give a better cosmetic result. Some surgeons, after cleaning out the mastoid process as thoroughly as possible, close the wound immediately, leaving only a small drain in the inferior angle, which they remove in a few days, if no reactive symptoms present themselves. In many cases this method works well, as the wound is closed within a few days, there is little external deformity, and the patient can return to his occupation within a very short time. Of course, this method is uncertain of success, as one can never tell if there is not some diseased tissue still in the wound cavity which would naturally prevent healing. In a number of cases in which the post-operative wound is slow in healing, one may hasten closure by filling the cavity with bismuth paste, as proposed by Beck of Chicago. This is allowed to remain for several days, and fresh paste added until the wound is entirely closed.

In March, 1913,‡ the writer proposed a method of closing the post-operative wound by bone transplantation, and performed this method in a number of cases with very gratifying results. The time of healing was not only greatly reduced, but the cosmetic result was excellent. The usual open method of packing and repacking the wound every third or fourth day is painful and tedious, not only to the patient, but also to the surgeon. Having observed the good results obtained by the general surgeon with bone transplantation, the writer thought it might be applicable to the vascular mastoid bone.

Technic of Bone Transplantation.—This procedure is carried out a week or ten days after the primary mastoid operation under a general or a local anæsthetic. A piece of bone is taken from the crest of the patient's tibia. Having removed the packing from the mastoid wound the edges are refreshed to obtain better union, but the granulating surface of the wound is not touched The length of the wound, is now measured, and a correspondingly sized piece of bone with its periosteum is removed from the tibia, as shown in Fig. 243. The detached piece of bone is carefully immersed in warm saline solution, and then placed into the. mastoid wound as quickly as possible in such a manner that its raw edges come into contact with the clean granulating surfaces of the wound. The skin is then sutured with the exception of

* *Transactions of the American Otolog. Society*, 1906.   † *Ibid.*
‡ M. J. Ballin, 'Tibial Bone Transplantation in the Post-Operative Mastoid Wound,' *New York Medical Record*, March 1, 1913; 'Remarks on Bone Transplantation in the Post-Operative Mastoid Wound,' *American Medicine*, vol. vii., No. 2, November, 1912.

a small orifice in the lower angle, in which there is placed a small gutta-percha drain. If at the end of a few days there is merely a slight mucous discharge, the drain is removed, and the wound allowed to close. The transplanted piece of bone is shown in Fig. 244, A and B. The air-space below the transplant fills up with a blood-clot, which becomes organized, and is eventually replaced by new bone, so that after a time the cavity becomes obliterated.

In performing bone transplantation, one must observe the following precautions:
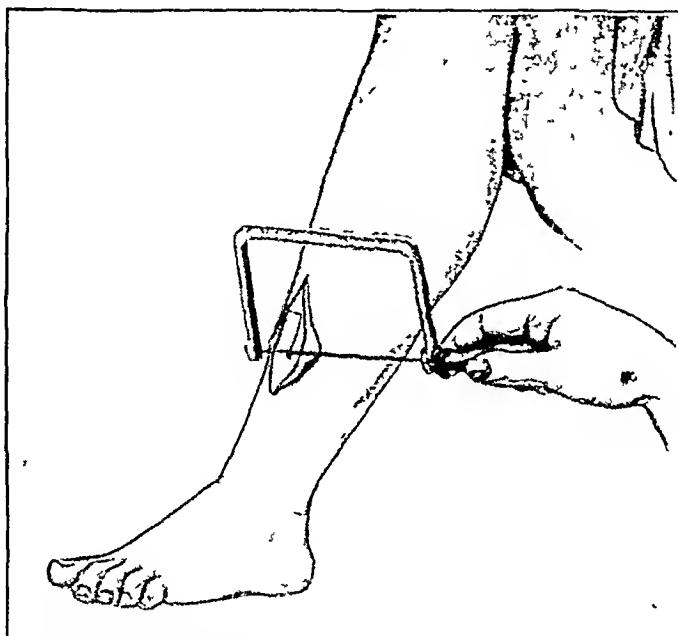
FIG. 243.—EXPOSED CREST OF TIBIA, SHOWING GIGLI SAW INTRODUCED THROUGH DRILL HOLE, AND BONE FLAP WITH PERIOSTEUM OUTLINED BY DOTTED LINES.

1. The post-operative mastoid wound must be free from purulent secretion and covered with healthy granulations.

2. The wound must not be curetted or bathed with antiseptic solutions.

3. Transplantation must be performed as a secondary operation, and may be undertaken a week, ten days, or even longer after the primary operation, depending entirely on the condition of the mastoid cavity.

4. The bone flap must be taken from the patient's own tibia; in other words, an autogenous transplantation.

5. Bone alone is insufficient; one must always take the bone with its living periosteum attached. This has been conclusively

demonstrated by the experiments of Ollier* as early as 1858, and confirmed later by Radzimowsky,† Marchand,‡ Bonome,§ and others, and more recently by Auxhausen.‖ The consensus of opinions of most investigators proves that in order to make a bone transplant viable it is imperative to preserve the healthy living periosteum.

6. The periosteum must not be injured; for, if it is, the ultimate result will be doubtful. The chances of success are much greater with an uninjured periosteum.

7. In making the bone flap, one must handle it as little as possible, so as to avoid injury and infection.
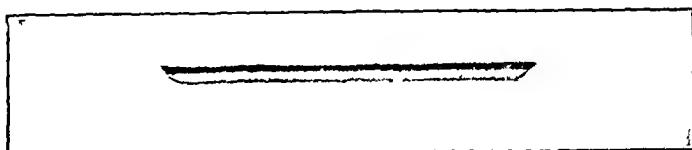
A
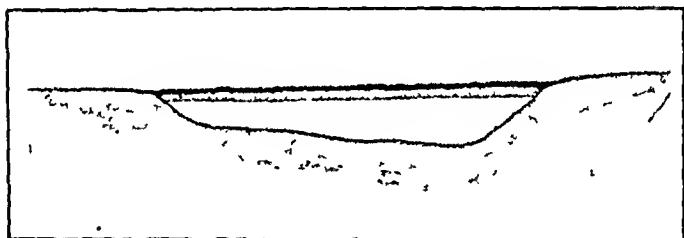
B

FIG. 244.—(A) LATERAL VIEW OF BONE TRANSPLANT, SHOWING LAYER OF ‑ PERIOSTEUM AND THE RAW BEVELLED EDGES. (B) MASTOID CAVITY, SHOWING BONE TRANSPLANT WITH ITS PERIOSTEUM IN POSITION AND AIR SPACE BELOW.

8. Inasmuch as a good blood-supply is absolutely essential to the successful issue of all kinds of transplantation, it is advisable to make use of this method only in such cases in which a good

* Ollier, ‘Des Moyens de Favoriser la Reproduction des Os,’ etc., *Gazette hebdomad*, No. 53, p. 304, 1858; *Brown-Séquard's Journal de Phys.*, 1859, p. 186.

† Radzimowsky (Russia), Diss. Kieff (1881), ‘Ueber Replantation und Transplantation der Knochen.’

‡ Marchand, ‘ Prozess der Wundheilung,’ etc., *Deutsche Chirurgie*, vol. xvi., 1901.

§ Bonome, translation in the *Virchow's Archiv für path. Anat.*, etc., vol. c., 1885, p. 293.

‖ Auxhausen, ‘Die pathologische—anatomischen Grundlagen der Lehre von der freien knochen—transplantation beim menschen und beim Tiere,’ *Beihefte zur medizinischen Klinik*, vol. iv., 1908, No. 2.

vascular bed for the transplant is present. This would exclude those cases in which there is a hard, ebonized, sclerotic mastoid bone.

Transplantation of the bone in mastoid surgery is a procedure which the writer does not advocate as a routine measure. He is of the opinion, however, that it is of value in cases in which there is a clean granulating wound, for if we succeed, we not only obtain a better cosmetic result, and greatly shorten the time of healing, but we also overcome the unpleasant packing and repacking of the wound, as is customary in the usual open method.

It may be stated that the procedure has one drawback, if one may call it so, and that is that the patient is subjected to a second general anæsthesia. However, the writer believes most patients will readily submit to this, if they can be convinced of the time and annoyance saved in the after-treatment. There is no doubt that the method is perfectly feasible under local anæsthesia, as already stated.

Exposure of the sinus and dura is no contra-indication to a bone transplantation, for if these parts are covered with healthy granulations, there is no reason why the result should not be satisfactory. There is no danger of a retention of pus beneath the transplanted flap with a secondary infection of the surrounding structures, as the sinus, etc. This is not likely to occur, for, if there is a suppurative process going on beneath the transplant, union will not take place, and the bone will be exfoliated within a very short time. Under such circumstances, transplantation will fail, and one is compelled merely to resort again to the usual open method of treating the wound. In other words, very little has been risked, and we have given the patient a chance for a more rapid and painless recovery.

Cases in which the wound does not run a favourable course are those in which, after opening the mastoid process, the wound fills more or less rapidly with granulation tissue, and a fistulous opening remains on the external surface of the mastoid process, through which, with the aid of the probe, rough bone can be recognized. Such fistulæ, remaining after the operation, may exist for months, even for years, without causing any symptoms and disturbance to the general state of the patient's health. In other cases the external opening of the wound cicatrizes after several weeks or months, but the scar breaks down— usually after a severe attack of pain—at one or more places. Such cases must be subjected to a second operation; the cavity is exposed and the spongy granulations and softened particles of bone thoroughly removed. In healthy individuals a cure, associated with a more or less retracted scar on the mastoid process, very soon takes place.

Even a second operation is not always successful. In such cases a cure can be obtained only by laying bare the middle-

ear spaces by more radical operative procedures (radical mastoid operation), the details of which will be described later (p. 525).

To the peculiar forms of acute mastoiditis with abscess formation we must reckon those cases in which the tympanic cavity is apparently free from all disease, or shows only symptoms of a mild catarrh.

There is no doubt that in this affection, which was formerly known as a primary acute inflammation of the mastoid cells, we have to do with a bacterial infection arising in the naso-pharynx, whereby the micro-organisms which reach the tympanic cavity lose their vitality, only to display their virulence again in the mastoid procéss. This affection is, as a rule, observed in pneumatic mastoids, in which either the terminal cells in the posterior part or all the cells are involved.

The symptoms accompanying this form of disease—namely, pain, sensitiveness on pressure, swelling of the integument, and the formation of a periosteal abscess with or without a communication* with the abscess cavity in the interior of the mastoid process—are no different than the symptoms in cases in which the suppurative inflammation has affected the entire middle ear and the membrana tympani has become perforated. At times, however, an abscess in the mastoid, which is associated with extensive destruction of its cells, develops with very mild symptoms of reaction. Recent investigations have shown that these slowly developing abscess formations, running a course almost without reaction, are due to the *Bacillus mucosus*.

The characteristic feature of this form of mastoiditis is the absence of reactive inflammatory symptoms in the tympanic cavity. The intact membrane is cloudy, lustreless, the blood-vessels of the handle of the malleus are injected, and the osseous canal is slightly reddened. The hearing is more or less impaired, just as in middle-ear catarrh.

If the affection lasts for a longer time and the abscess in the mastoid is not opened, the suppuration may extend to the tympanic cavity and lead to perforation of the drum. The occurrence of a primary osteomyelitis with empyema of the mastoid, without a previous diseased condition of the tympanic cavity, is questionable. Primary tubercular mastoiditis has been frequently observed in childhood.

The treatment is no different from that of the usual acute mastoiditis.

Primary inflammations of the periosteum without involvement of the interior of the mastoid are very rare, and occur more often in adults than in children. They are most often produced by furunculosis of the

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* Rohrer, *La périostite secondaire de l'apophyse mastoïde. Archiv intern. de Rinol., Laring. y Otologia*, Barcelona, 1893. Lenhardt, *Sur un cas de mastoïdite sans otite. Rev. hebd. d. laryng.*, 1901.

posterior wall of the external meatus, or through trauma. The inflammation involves only a circumscribed area, or it extends over the whole mastoid up to the temporal region. It is characterized by the formation of a hard, usually red, swelling on the mastoid, which is very painful on pressure. At times the upper part of the sterno-cleido-mastoid muscle (Knapp) is involved in the process, which causes a rigidity of the neck. Symptoms of inflammation are lacking on the drum or in the meatus; only rarely do the posterior wall of the meatus and the handle of the hammer appear injected.

The most prominent symptom is a severe radiating pain in the mastoid, which increases on slight pressure and on motions of the head. The skin temperature of the inflamed part is increased, and the function of hearing is normal or somewhat diminished owing to a consecutive middle-ear catarrh. With the formation of an abscess the fever, which is generally slight, reaches a higher degree.

The inflammation reaches its climax within several days. An absorption of the inflammatory infiltration is seldom observed. On the other hand, as the observations of Roosa and Ely (*Z. f. O.*, vol. ix.), Webster (*Arch. of Otol.*, vol. viii.), Knapp, Lewi, Lue, and the author show, it goes on to the formation of an abscess with spontaneous perforation externally, or into the external auditory canal through one of the fissures of Santorini. Occasionally the inflammation leads to a superficial painless necrosis of the cortical layer of the mastoid process (Politzer), with the exfoliation of several small fragments of bone (Hotz).

Diagnosis.—The diagnosis of primary acute periostitis of the mastoid process is made from the objective changes on the mastoid process in conjunction with the simultaneous non-appearance of inflammatory phenomena in other parts of the temporal bone. If the case is examined superficially, it can be confounded only with the painful swellings on the mastoid process which sometimes arise with deep-seated furuncles on the posterior wall of the auditory meatus, or with the seldom occurring primary inflammation and suppuration of the lymph-glands on the mastoid process (Jürgens).

Prognosis.—The prognosis of primary acute periostitis of the mastoid process is, as a rule, favourable.

Treatment.—The treatment consists in the energetic application of antiphlogistics, and in incision of the swelling to the periosteum (Wilde's incision) in case the inflammatory symptoms do not disappear within two to three days. In cases in which the exudate has not yet become purulent, the inflammation sometimes subsides without suppurating after incision of the swelling. When fluctuation shows that an abscess has formed, it is evacuated by means of a broad incision, and packed with gauze.

B. Diseases of the Mastoid Process developing in the Course of Chronic Middle-Ear Suppurations.

In chronic, just as in acute, middle-ear suppurations, the antrum and mastoid cells are more or less involved in the inflammatory process. The character and extent of the mastoid disease depend on the anatomical variety of the mastoid process, on the pathological changes in the middle ear, on the location of the perforation in the drum, on the duration of the disease, and on the general condition of the patient (tuberculosis, syphilis, etc.). Accordingly, the most extensive disease is found in the pneumatic variety, whereas the vertical part of the diploëtic mastoid process is less often involved in the suppurative process. The antrum is always the seat of pathological changes.

The following local processes favour the development of patho-logical changes in the mastoid process in chronic middle-ear suppuration: narrowing of the external meatus, perforations at the circumference of the posterior superior quadrant of the membrana tympani, adhesion of the drum membrane to the inner wall of the tympanic cavity, obliteration of the cavum tympani and mastoid antrum by polypi, granulations, and cholesteatomatous masses, and suppurations in the attic associated with perforation of Shrapnell's membrane. In such cases the most important factors are the obstruction to the outflow of secretion, and the stag-nation, retention, and decomposition of purulent and caseous masses in the mastoid process, which lead to its absorption and cario-necrotic disease.

The most important pathological changes in the mastoid process in chronic middle-ear suppuration are: (1) Hypertrophy of the lining membrane of the antrum and mastoid cells, and complete obliteration of these cells. The granulation tissue which fills these pneumatic spaces may persist or ossify. (2) Granular ostitis and carious softening of the walls of the mastoid antrum, which is frequently abnormally widened; narrowing or complete obliteration of the antrum with sclerosis of the mastoid process is rare. (3) Circum-scribed or diffuse caries and necrosis of the mastoid process, with or without the formation of a sequestrum. (4) Cholesteatomata in the antrum and in the mastoid cells, or a collection of pus and thickened, caseous masses similar to tubercular material. (5) Hyperostosis and osteo-sclerosis* of the bone-substance surrounding the seat of the disease. These changes are hardly ever confined to the mastoid process, but are usually combined with caries, granu-lations, or cholesteatomata in the cavum tympani or in the attic.

The destructive processes in the tympanic cavity and in the mastoid process which frequently develop in middle-ear suppura-tions often date from childhood. Most of these destructive changes are brought about by the suppurative middle-ear processes of the infectious diseases and tuberculosis, as well as by cholesteatomata in the middle ear. As regards the extension of the destructive process, it has been shown that this is greater in pneumatic than in diploëtic mastoids. In the latter, one finds not only caries, granulations, and cholesteatomata in the attic and in the mastoid antrum, but also the vertical part is frequently involved in the diseased process. Enlargement of the antrum through destruction of its walls is one of the most common conditions.

Symptoms.—Chronic inflammations of the mastoid process may run their course without symptoms for many years. This applies especially to hypertrophy of the lining membrane of the mastoid cells, which leads to obliteration of the cells and to eburnation of the mastoid process. Still, cholesteatomata, carious softening of the bone, and sequestra may also exist for a long time without causing any objective or subjective symptoms.

* J. Orne-Green, *Osteo-Sclerosis of the Mastoid* (*Transactions of the American Otol. Society*, Thirteenth Annual Meeting, vol. ii., part iv.).

If, in these cases, an intercurrent, acute inflammation develops in the mastoid process, violent symptoms arise, which in intensity often surpass those accompanying an acute primary inflammation of the mastoid process. The most prominent symptoms are: violent beating and piercing pains in the mastoid process which radiate towards the cervical region, marked tenderness on pressure, especially in the middle and superior parts of the mastoid, slight or high fever, sleeplessness, headache, tinnitus, dizziness, and vomiting. If the disease has its seat in the deeper parts of the bone, the external integument of the mastoid process remains unchanged even after a long duration of the inflammation; this is especially true in diploëtic and compact mastoid processes if the suppuration is confined to the mastoid antrum. If the seat of the inflammation is very extensive and reaches up to the cortical layer, a diffuse, red, hard, or slightly fluctuating swelling develops on the mastoid process; this sometimes takes place gradually, sometimes rapidly, and when such is the case it extends posteriorly and upwards towards the vertex. It causes the auricle to stand away from the head, and may occasionally be associated with an œdema extending to the eyelids of the corresponding half of the face, and with a collum obstipum.

On inspection, the perforated membrana tympani, which is often adherent to the promontory, appears swollen and covered with granulations, and the perforation is occluded by pulsating secretion, by polypoid masses growing out of the tympanic cavity, or by cholesteatomata. The discharge, which is sometimes profuse and sometimes scanty owing to an obstruction to the outflow of pus, either resembles meat-juice, or it is thick, curdy, and foul-smelling. The lining of the auditory meatus is not infrequently infiltrated, and the lumen of the canal narrowed and even impermeable, owing to the bulging of its posterior superior wall, or to hyperostoses of the bony walls.

Course and Terminations.—Slight intercurrent inflammations in the mastoid process, which are sometimes observed in the course of chronic middle-ear suppuration, may subside without the formation of an abscess. There is no doubt that such inflammations often form the starting-point of an osteo-sclerosis or a caseous ostitis of the mastoid process. When the intercurrent inflammation in the mastoid process leads to the formation of an abscess (in cases in which the suppurative process or cholesteatomatous masses have existed for a long time), it either perforates externally on the cortical layer, or inferiorly at the incisura mastoidea, or it may discharge into the external auditory canal or into the cranial cavity or sigmoid sinus.

The inflammation in the mastoid process, accompanied by abscess formation, arising in the course of a chronic middle-ear suppuration, develops with severe symptoms of reaction, which

are caused either by an obstruction to the outflow of the pus or by the impaction of a sequestrum. The progressive destruction thus produced may spread in different directions in the mastoid process and break through its borders.

A breaking through of the mastoid process most frequently takes place at the external cortical layer at the fossa mastoidea or at its middle part. This usually takes place with symptoms of severe congestion, and with the formation of a swelling over the mastoid and in its vicinity. The infiltration, which is at first hard, shows a distinct fluctuation after the breaking through of the cortical layer. If, in such cases, the abscess is not opened, it may break through the soft tissue in one or more places. Often the opening in the skin corresponds to the place where the cortical layer has been perforated, but not infrequently, however, the opening in the skin lies at a distance from the fistula in the bone, which is found only when the planum mastoideum is exposed by operation. When such fistulæ on the mastoid, which occur generally in children, are exposed, one usually finds a purulent cavity surrounded by carious walls and filled with fragments of bone and caseous masses, the posterior and superior walls of the meatus and the external attic wall destroyed, and the tympanic cavity filled with caseous pus. More often, however, especially in children, the cavity in the mastoid process, after the exfoliation of a sequestrum, is filled with ossifying connective tissue, whereupon recovery takes place with the forma-

Fig. 245.

a, Cavity of abscess in mastoid process; *b*, Site of rupture on the posterior superior wall of the meatus; *c*, Lining membrane of the meatus reaching to the anterior inferior wall; *d*, Inner portion of the external auditory meatus; *e*, Tympanic cavity.

tion of a retracted scar on the mastoid process, and sometimes also with atresia of the auditory canal.

In other cases, after the exfoliation of diseased particles of bone, a cavity remains which is lined with scar-tissue and epidermis. In addition to such a cavity, a fistulous opening sometimes remains which is often large and lined with epidermis, and through which a part of the cavum tympani and the tympanic orifice of the osseous Eustachian tube may be seen.

Rupture of the mastoid abscess through the posterior superior wall of the osseous meatus takes place occasionally (Fig. 245). This is often preceded by a protracted inflammation of the periosteum of the auditory canal, together with marked swelling and bulging of its lining membrane.

When an abscess breaks through spontaneously, large granulations spring up at the edges of the place of perforation. This may lead us to believe that we are dealing with a polypus, until the escape of purulent or caseous secretion between the granulations, as well as the examination with a probe, reveal the presence of a fistulous opening,

In other cases the abscess breaks through in different directions—for example, on the cortical layer and into the external meatus. After such diseased processes in the bone have been cured, the author has seen a canal lined with epidermis passing through the mastoid process, one fistulous opening of which was on the external cortical layer and the other in the external auditory canal. Cases have also been observed in which the abscess has broken through externally on the cortical layer and internally into the cranial cavity with the formation of a subdural abscess. In one case there was a prolapse of the brain through the external osseous opening. The formation of fistulæ in the semicircular canals and in the labyrinthine wall of the tympanic cavity will be discussed in a special chapter.*

Cases in which the mastoid abscess makes its way through the incisura mastoidea, or perforates the medial side of the mastoid process are of less frequent occurrence (Bezold's mastoiditis). This is especially likely to occur in pneumatic mastoid processes in which the lower part consists of a large, thin-walled, osseous bulla (terminal cells), or of several large, pneumatic spaces which, inferiorly and medially, are bounded by an osseous lamella often as thin as paper. This form occurs almost exclusively in adults.

The breaking through of the abscess on the inferior and medial sides of the mastoid process often leads to complications of long duration, inasmuch as the pus bores through the subfascial layers of the neck between the muscles, and along the sheaths of the large vessels. This results in an extensive painful infiltration of the cervical region beneath the mastoid process (Guye, *Zeitschr. f. Ohrenheilk.*, vol. xxiii.). The subfascial abscesses thus produced usually make their way externally to the lateral region of the neck, or ' sinking abscesses ' develop which cause serious complications, in that they sometimes lead to a fatal termination in consequence of a pyothorax or compression of the trachea (Jacobi).†

The diagnosis of rupture of an abscess on the medial surface

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* In reference to the intracranial complications after the breaking through of an abscess of the mastoid process into the cranial cavity and sigmoid sinus, the reader is referred to a special chapter.

† Delie, *Un cas de mastoïdite de Bezold* (*Bull. de la soc. belge d'otol.*, 1897); Ernst Urbantschitsch, *Otogene Senkungsabszesse* (*Wiener med. Presse*, 1904); Moure, *Seize cas de mastoïdite de Bezold* (*Rev. hebd. de laryng.*, etc., 1901).

of the mastoid process can be made, if the pain in the mastoid process continues, and a hard, tender swelling develops below it which extends towards the cervical region, while the integument covering the mastoid region shows little or no infiltration.

Diagnosis.—The diagnosis of mastoiditis occurring in chronic middle-ear suppuration, and appearing with symptoms of reaction, is made from the same group of symptoms as that which accompanies an acute mastoiditis (p. 491). The diagnosis is much more difficult in those chronic diseases of the mastoid process which so often run a latent course without any symptoms. At the same time, it is often possible, in cases in which externally there is nothing to show that a mastoiditis exists, to conclude with great probability, from a certain symptom, that a mastoid disease is present—as, for instance, an attic suppuration. Such a symptom is a persistent, septic, caseous discharge which is associated with perforation in the posterior superior quadrant of the membrana tympani, or with a fistulous opening in Shrapnell's membrane.

The diagnosis is more probable if, with moderate secretion in the tympanic cavity, a larger amount of pus is aspirated from the posterior superior portion of the attic into the external meatus by repeatedly rarefying the air in the latter with Siegle's speculum than the superior tympanic cavity is capable of holding. The diagnosis is also substantiated if, simultaneously with the suppuration, boring pains in the mastoid process frequently recur with symptoms of pus stagnation or cholesteatomatous formation, with or without swelling of the integument. On the other hand, pain in the mastoid process when the external cortical layer is unchanged cannot always be taken for a symptom of suppuration in the mastoid process, as it also occurs in neuralgia of osteo-sclerotic mastoid processes. In such cases the diagnosis is often made only after careful observation. On the other hand, if there are granulations and cholesteatomata in the tympanic cavity, or if there is a narrowing of the external meatus with symptoms of pus retention, we may conclude that there is a diseased condition of the mastoid, even if its external appearance is normal, and is not sensitive on pressure.

Prognosis.—The prognosis of disease of the mastoid process accompanying chronic middle-ear suppuration, as far as the results of opening up the seat of the disease by operative procedures are concerned, is more favourable if, at the time of operation, no dangerous symptoms are present. The prognosis is less favourable if, in cases of co-existent caries of the walls of the cavum tympani, obliteration of the tympanic cavity by granulations and cholesteatomatous masses, and excessive narrowing of the auditory canal, there are symptoms of an intracranial complication or of a sinus phlebitis. As a rule, the

prognosis of diseases of the mastoid process is unfavourable in cachectic and tubercular individuals.

Treatment.—The treatment of diseases of the mastoid process arising in the course of a chronic middle-ear suppuration, and developing with marked reactive symptoms, is principally operative, and is the same as the surgical treatment of chronic middle-ear suppuration, which will be described later. Since our knowledge of the frequent occurrence of the destructive processes in the cavum tympani and in the mastoid process accompanying middle-ear suppurations has been considerably increased by anatomical investigations and by the operative opening of the middle-ear spaces, the conservative treatment of these affections has become considerably limited. Conservative treatment is indicated only in cases in which the diagnosis of antral or middle-ear suppuration has been made, and the process runs its course without any marked symptoms.

Conservative treatment (p. 425) must be rejected in all those cases in which, during the course of a persistent chronic middle-ear suppuration, pains in the mastoid process repeatedly occur, with or without swelling of the external integument, and where there is danger of the suppuration extending to the meninges or to the sinus. In such cases the urgency of an operation* for opening up the purulent cavity should always be suggested to the patient. The indication for the operation is all the more urgent if the aural examination points with absolute certainty to a diseased condition of the bone in the mastoid process. As such may be mentioned: antral suppurations associated with a perforation at the circumference of the posterior superior quadrant of the membrana tympani, granulations and cholesteatomatous masses in the cavum tympani, and a deposit of epidermis adhering to the remnant of the membrana tympani and to the wall of the promontory.

The Radical Mastoid Operation.

The surgical treatment of chronic middle-ear suppuration, as it is performed at present, is one of the most valuable advances in modern otology. By this treatment we are not only enabled, in many cases which were formerly considered incurable, to arrest the middle-ear suppuration and to prevent the development of complications dangerous to life, but also to treat cerebral complications of otitic origin successfully.

The older communications on the operative opening of the mastoid process for therapeutic purposes† are of little practical value. Its importance was brought out by the writings of

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* De Rossi, *Contribuzione allo studio della medicina operatoria dell'orecchio*, etc., Rome, 1878.

† Politzer, *Geschichte d. Ohrenheilk.*, 1907, pp. 327 and 328.

v. Tröltsch and by the praiseworthy works of Schwartze (1873), which were published in an epoch in which clinical observations were advanced in a masterly manner by pathological investigations.

The typical opening of the mastoid antrum in chronic middle-ear suppuration, as introduced into aural surgery by Schwartze and practised for several decades by otologists, serves the purpose of establishing a communication between the seat of the disease in the mastoid process and the cavum tympani, whereby it is possible to wash out the middle ear, and to remove the septic, stagnant secretion.

Experience has shown that in the majority of cases in which the operative treatment of chronic middle-ear suppuration is indicated, this method is insufficient, in so far as a permanent cure is seldom obtained by opening the antrum alone. This is explained by the fact that the disease in the bone is seldom confined to the mastoid process or antrum, but is mostly associated with caries of the walls of the tympanic cavity and external auditory canal, or with cholesteatomata in the attic.

Therefore, methods of operation have come into use which aim at the thorough removal of all the diseased tissue in the temporal bone, and the free exposure of the purulent cavity.

Küster deserves the credit of having devised a method by which the suppurative process in the temporal bone can be successfully treated by surgical means.*

He was the first to propose that we take away principally the posterior wall of the osseous meatus for the purpose of opening up the middle-ear spaces. His idea was based on the fact that when a suppuration is confined within rigid walls, the seat of the disease should be widely opened, and that the purulent cavity should be completely laid bare by the removal of all the diseased tissue. This idea of Küster's forms the basis of the methods of opening up the middle-ear spaces, which have been considerably modified and perfected, and which acquired the term of the 'radical mastoid operation' in otological practice.

Von Bergmann's operation differs from Küster's in that the inferior lamella of the superior wall of the osseous meatus, together with the external wall of the attic, is removed in layers, and the posterior wall of the auditory canal is then chiselled away and the antrum opened up.†

Stacke and Zaufal deserve the credit for having perfected the technic of the radical operation. Their methods are not analogous, in so far as Stacke, after detaching the auricle and the cartilagino-membranous meatus, first opens up the attic and then the antrum, whereas Zaufal opens the antrum and

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* *Ueber die Grundsätze der Behandlung von Eiterung in starrwandigen Höhlen* (*Deutsche med. Wochenschr.*, 1889).

† *Die chirurgische Behandlung der Hirnkrankheiten*, 1889.

attic only after having thoroughly chiselled away the anterior part of the mastoid process and the posterior superior wall of the auditory canal.

These methods of operation, which have been considerably modified and improved, will be spoken of more fully later on. The author would like to mention here, by way of introduction, that at his clinic, as well as at others, methods of operation for opening up of the middle-ear spaces have been tried, which, in some respects, deviate from the typical radical operation. In spite of all modifications, the common aim of all operative procedures is to change the cavum tympani, the attic, and the antrum into one common, smooth-edged, open cavity by the removal of the posterior superior wall of the osseous meatus and the external attic wall, and, furthermore, to induce the surface of the wound to become covered with epidermis and to cicatrize by a careful after-treatment.

Indications.—The indications for opening up the middle-ear spaces in chronic middle-ear suppuration are based upon the general clinical picture produced by the objective and subjective symptoms of the aural affection. It will be seen that in some cases only the objective condition of the organ of hearing, in other cases, again, a group of subjective symptoms alone, make the radical operation for opening up the middle-ear spaces necessary, and that often, however, a combination of both groups of symptoms is essential.

The objective conditions which indicate the radical operation in chronic, persistent, middle-ear suppurations are the following:

1. Caries of the temporal bone.

2. A recurring growth of polypi in the tympanic cavity which arises from the attic and antrum.

3. Fistulous openings on the mastoid process and in the osseous meatus.

4. Cholesteatomata in the middle ear if conservative treatment of the middle-ear suppuration proves futile.

5. Obstinate, antral suppurations in which a peripheral fistula is present at the posterior superior quadrant of the membrana tympani.

6. Strictures of the external meatus which cannot be relieved.

7. Paresis or paralysis of the facial nerve.

8. Intercurrent acute mastoiditis, with the formation of a mastoid abscess.

9. Fœtid middle-ear suppurations resisting every kind of long-continued local treatment.

Other symptoms in combination with the objective conditions, which indicate the radical operation in chronic middle-ear suppuration, are:

1. Remittent or continuous fever, chills, or the characteristic septic fever with rapid variations in the temperature.

2. Vomiting, when it occurs with headache and symptoms of cerebral irritation.

3. Retinitis optica, papillitis, and choked disc.

4. Continuous or often-recurring pains in the ear or in the mastoid process, or persistent headaches on the corresponding side of the head.

5. Temporary attacks of dizziness or continuous dizziness and symptoms of a secondary labyrinthine suppuration.

6. The first signs of cerebral complication, as severe headache, nausea, and vomiting.*

Marked symptoms of otitic meningitis, which, as we are aware, offer the smallest possible chance of success, do not contra-indicate the opening up of the middle-ear spaces (Lucae, Barth). This is especially true of meningitis serosa,† which runs its course with the usual symptoms of meningitis, and in which the cerebro-spinal fluid, free from pus cells, is obtained by lumbar puncture; also of cases in which the fluid contains leucocytes and bacteria.

The opening up of the middle-ear spaces in otitis media suppurativa tuberculosa, which is performed only in urgent cases, depends on the state of the pulmonary affection. In cases in which the objective symptoms and rapid emaciation leave no doubt that the case is one of incipient pulmonary tuberculosis, the radical operation not only at times stops the suppuration in the ear, but also acts favourably on the pulmonary affection and on the general health of the patient. On the other hand, according to observations made at the author's clinic, a fatal termination is only hastened by performing the radical operation in cases in which there is a marked phthisis. Nevertheless, Brieger will not even grant that pulmonary tuberculosis is an absolute contra-indication to the radical operation.

Finally, it is questionable whether it is justifiable to perform the radical operation for the cure of persistent, uncomplicated middle-ear suppurations to such an extent as is done by some specialists. Those who adhere to this radical standpoint refer to those cases of chronic middle-ear suppuration in which the affection often runs a symptomless course, and in which extensive changes are found in the antrum and mastoid process without symptoms ever having occurred to show that these parts were diseased. Therefore, owing to the more favourable prospects of recovery offered by the early operation, one should not wait until dangerous symptoms appear, as they make the prognosis very bad.

In opposition to this, conservative authors advance the opinion

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* Cp. Macewen, Lucae, Knapp, and Politzer, *Indications for opening up the Middle-Ear Spaces in Middle-Ear Suppurations.* Sixth International Otological Congress, London, 1899.

† See chapter on Intracranial Complications, p. 567.

that in many cases, middle-ear suppurations may continue for decades—even during the life of the patient—without complications, and that not infrequently a persistent middle-ear suppuration may be cured without the radical operation by a thorough local treatment (by the removal of granulations and polypi from the tympanic cavity and attic, and by scraping away rough bone on the external attic wall).

Therefore, in all cases of persistent middle-ear suppuration in which the objective and subjective symptoms, so paramount for the operative indication, are lacking, we must always try to control the suppuration by a thorough local treatment before
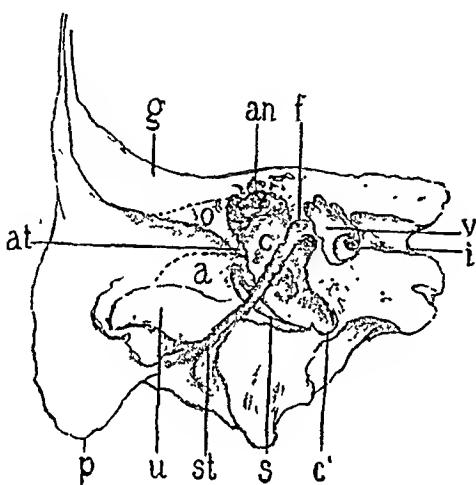
FIG. 246.—FRONTAL SECTION THROUGH THE RIGHT TEMPORAL BONE.

g, Superior wall of the meatus; *u*, Inferior wall of the meatus; *p*, Mastoid process; *c*, Posterior wall of the tympanic cavity; *c'*, Inferior wall of the tympanic cavity; *an*, Antrum; *f*, Section of the facial canal on the inner wall of the tympanic cavity; *st*, Place of exit of the opened descending part of the facial canal (stylomastoid foramen); *at*, Margo tympanicus of the external attic wall; *o*, The part of the inner division of the superior wall of the meatus which must be chiselled away when exposing the attic; *a*, Compact part of the posterior wall of the meatus; *i*, Internal auditory meatus; *v*, Vestibule.

resorting to operative procedures. It must also be borne in mind that, by performing the radical operation, the patient is compelled to give up his work for weeks or months, and that not infrequently the hearing gets worse, or is almost completely lost.

Rare conditions which sometimes indicate the opening up of the middle-ear spaces are impacted foreign bodies or sequestra in the tympanic cavity, and that rare form of disease of the temporal bone known as actinomycosis. According to the cases described by Majochi, Zaufal, Cozzolino, Reinhard, and Ten Siethof, actinomycosis is generally due to a secondary infection of the temporal bone caused by the ray fungus; only in the case

reported by Zaufal is the disease supposed to have started from the ear itself. The affection, which runs a course similar to that of a middle-ear suppuration, is characterized by the appearance of abscesses and hard infiltrations in the neighbourhood of the ear, and by cores within the abscesses, which have a yellowish or greenish appearance; the cores contain the oscillated or ramified filaments of the fungus with their coccidia-like processes arranged in a radiating manner. The termination is usually, fatal from metastases in the brain.

Operative Methods for opening up the Middle-Ear Spaces.

Anatomical Remarks.—In order to have a better idea of the operative procedure in performing the radical mastoid operation, it might be of value to point out a few details regarding the
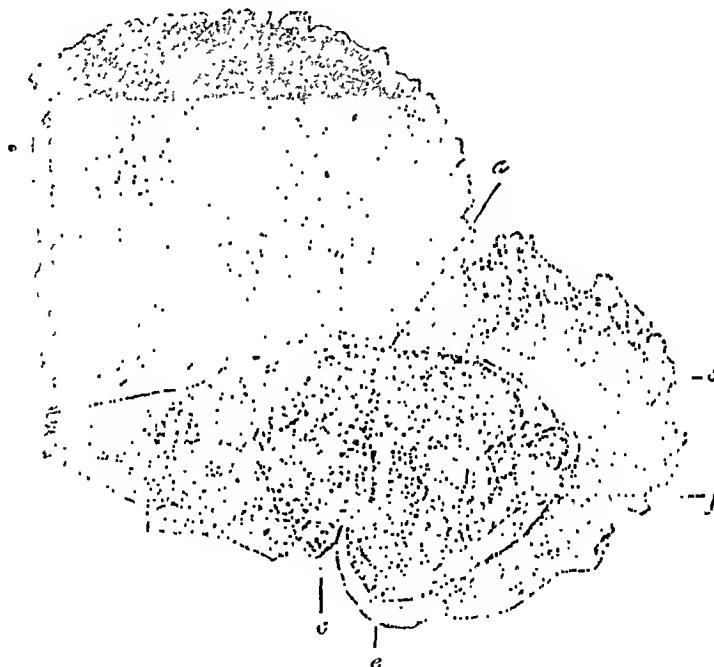
Fig. 247.—The Opened-up Middle-Ear Spaces in a Left Temporal Bone.

a, Attic; *b*, Antrum; *c*, Cavum hypotympanicum; *d*, Fenestra vestibuli (ovalis); *e*, Facial canal, and above it the prominence of the horizontal semicircular canal; *f*, Sinus.

anatomical relation of the antrum to the auditory meatus, and to consider the topographical relation of the descending part of the facial canal. In the pneumatic mastoid processes the antrum is, as a rule, more spacious than in the diploëtic.

In the pneumatic mastoid the posterior part of the antrum lies considerably more external than the cavum tympani, so that a sagittal section passing through the middle of the osseous meatus

strikes the external border of the antrum. In such a case, but still more often when the antrum is pathologically widened, the cavity of the antrum is opened at a short distance from the external auditory foramen when removing the posterior superior wall of the meatus, while, on the other hand, when the antrum is small, this is possible only when we have reached the posterior superior border of the membrana tympani.

When chiselling away the posterior superior wall of the meatus and the external wall of the attic, the topographic relations of the facial and horizontal semicircular canals must be especially considered,* as an injury to these parts is one of the unpleasant occurrences in the radical operation. If, on a frontal section through the tympanic cavity (Fig. 246), the course of the facial nerve is followed from the inner wall of the cavum tympani (*f*) to the stylo-mastoid foramen (*st*), it is found that the Fallopian canal often takes an oblique course which is strongly directed outwards, so that a vertical line projected from the stylo-mastoid foramen would almost touch the middle of the inferior wall of the meatus. In its course the facial nerve (*f*, *st*) passes through the compact bone substance (*c*) situated below the antrum, which connects the posterior and inferior walls of the meatus with the pyramid (Fig. 246, area *c*). This so-called facial spur must be especially avoided when opening up the middle-ear spaces, owing to the danger of injuring the facial nerve.

Of just as much importance in the radical operation is the chiselling away of the posterior superior wall of the meatus and the external wall of the attic. The accompanying cut (Fig. 247) is taken from a macerated temporal bone, and shows, in addition to the cavum tympani and antrum, a large part of the mastoid process and plate over the sigmoid sinus.†

The operation for opening up the middle-ear spaces from the mastoid process (the radical mastoid operation) is divided into the following steps:‡

1. **Exposure of the external surface of the field of operation.**
2. **Opening up the middle-ear spaces.**
3. **The plastic operation.**
4. **The after-treatment.**
5. **The eventual operative treatment of intracranial complications.**

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* Cp. Randal, *Zeitschr. f. Ohrenheilk.*, vol. xliv.

† For the study of the topographic relations of the temporal bone in reference to the radical operation the following works are recommended; Trautmann, *Die chirurgische Anatomie des Schlafebeins*, Hirschwald, 1898; A. Politzer, *Die anatomische und histologische Zergliederung des menschlichen Gehörorgans*, Enke, 1889; Gerber, *Hand atlas der Operationen am Schlafebein*, Wiesbaden, 1904.

‡ Refer to p. 499 for the instruments as well as the preparations required in performing the operation.

1. Exposure of the External Surface of the Field of Operation.

The field of operation is prepared in the same manner as in the simple opening up of the mastoid process. The radical operation can be performed under a general or local anæsthesia. For local anæsthesia one can use a novocaine solution, aposthesine, or any of the other local anæsthetics. Some of the solution is injected under the periosteum at the fossa mastoidea and at the centre and apex of the mastoid; several c.cm. are also injected under the periosteum of the posterior wall of the external meatus, in that one introduces the needle directly behind the place of attachment of the auricle. and advances it as far as the region of the antrum. Finally, several c.cm. are injected into the four walls of the meatus under the periosteum at the place of union of the cartilaginous and osseous canals. If the parts are well infiltrated, the operative procedure is comparatively free from pain, but the patient experiences the unpleasant sensation of hearing the chiselling of the bone. There is quite severe pain, however, when the antrum is reached, and when we endeavour to curette this part. That the operation can be fully carried out under a local anæsthesia is a well-established fact, and is sometimes necessary in cases of advanced age, marked diabetes, and in persons having severe heart lesions.

Exposure of the field of operation is carried out just as in the ordinary acute mastoid operation (p. 500). The incision is made down to the cortex of the mastoid process, the periosteum is pushed back, and the bone freely exposed.

2. The Complete Opening up of the Middle-Ear Spaces (The True Radical Mastoid Operation).

After having exposed the field of operation, the planum mastoideum and osseous meatus are examined to see if there are any carious areas or fistulous openings.

If the external surface of the mastoid process presents a normal appearance, several layers of bone are then removed just as in the acute mastoid operation, and the mastoid bone freely laid open (Fig. 248). Inasmuch as further layers of bone are chiselled away from the posterior superior wall of the meatus, a funnel-shaped wound is made, the convexity of which is directed backwards and upwards, the apex forwards and inwards towards the tympanic cavity.

When the antrum is normal, or abnormally widened by caries and cholesteatomata, its external part is reached only a short distance from the cortical layer of the mastoid process when chiselling away the posterior superior wall of the meatus. The external boundary of the antrum corresponds nearly to the middle of the posterior wall of the osseous meatus (Fig. 248, *an*).

The opening in the antrum (Fig. 248, *an*) is now widened by means of a narrower chisel, and the granulations or cholesteatomatous masses filling the cavity are removed with a sharp, oval curette.

Before chiselling away the internal section of the posterior superior wall of the osseous meatus (*p*), it is advisable to lay bare the opened antrum on all sides. It is therefore necessary to take away all the bone which overhangs the antrum until its most posterior border is open to view.

For this purpose Stacke's protector (Fig. 249) can be employed, which is of value in performing the radical operation.
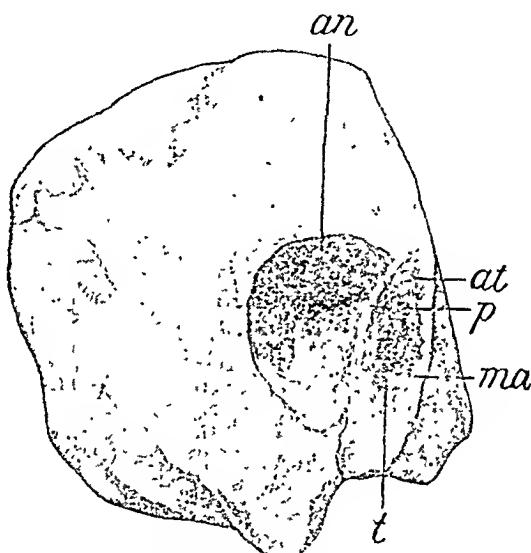
FIG. 248.—A VIEW OF THE FIRST PHASE OF THE RADICAL OPERATION.

an, The lateral part of the mastoid antrum, opened by chiselling away the posterior superior wall of the meatus; *at*, External wall of the attic; *p*, The still remaining internal section of the posterior wall of the meatus, separating the antrum from the attic; *ma*, Anterior wall of the osseous meatus; *t*, Membrana tympani.

After having laid open the antrum, scraped out all the diseased bone, and carefully examined the cavity to see if there are any fistulous openings leading to the cranial cavity or sinus, the internal part of the osseous meatus and the external attic wall (Fig. 250, *at*) are then chiselled away. For this purpose either a pointed bone forceps or a narrow chisel can be used.

After the removal of this plate of bone the uninterrupted communication between the attic, antrum, tympanic cavity, and external meatus is established, and it only remains to chisel away all the overhanging and projecting osseous walls, the most important of which is the external attic wall.

If the external attic wall is so completely removed that the tegmen tympani is on a plane with the partly chiselled away

superior wall of the meatus, and the protector, as it is drawn from the attic towards the superior wall of the osseous meatus, meets with no resistance, the contents of the attic is then scraped out with a narrow curette, its walls made smooth, and the tegmen tympani examined with a probe to see if there are any defects or necrotic areas in the bone.

Attention must then be directed to the tympanic cavity which lies farthest anteriorly and inferiorly. It must be mentioned that even after completely laying open the attic and antrum, the
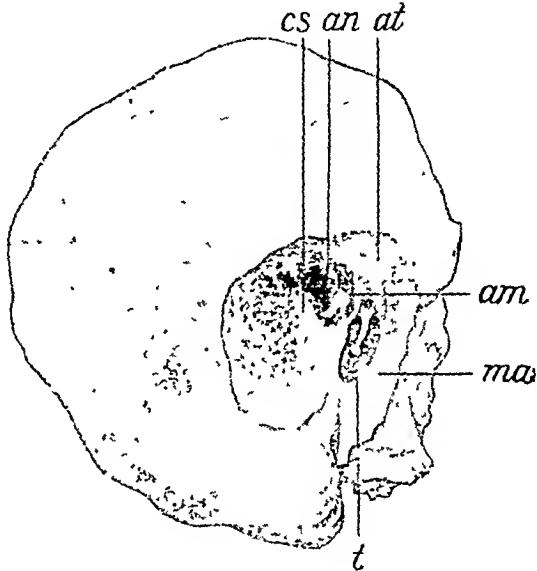
FIG. 250.—VIEW OF THE FIELD OF OPERATION AFTER OPENING UP THE ANTRUM AND BEFORE THE REMOVAL OF THE OSSEOUS BRIDGE OF THE POSTERIOR SUPERIOR WALL OF THE OSSEOUS MEATUS.

cs, The prominence of the horizontal semicircular canal; an, Mastoid antrum; at, External attic wall; am, Osseous bridge between the attic and antrum; ma, Anterior wall of the meatus; t, Membrana tympani.

FIG. 249.

tympanic cavity is still partly hidden from view by the so-called facial spur and the posterior wall of the osseous meatus lying external to it. Therefore, in order to bring the cavum tympani and its floor (*cavum hypotympanicum*) into view, it is necessary to remove the uppermost portion of the facial spur and a part of the posterior wall of the osseous meatus lying external to it. This manipulation requires the greatest caution, owing to the danger of wounding the facial nerve. During this stage of the operation an assistant must immediately inform the operator if there are any twitchings or contractions of the muscles of the

face. If the nerve has been irritated or slightly injured, these twitchings become very marked. When the nerve has been severely injured, a more or less pronounced facial palsy becomes manifest during the operation or shortly after. With the same precautions a part of the posterior portion of the sulcus tympanicus is removed. In order to bring the floor of the tympanic cavity on a level with the inferior wall of the meatus, and to create a good drainage for the secretion in the cavum hypotympanicum, the innermost border of the inferior wall is also removed. This is indicated, however, only when the floor of the tympanic cavity lies very low. Hammerschlag (*Wiener klin. Wochenschr.*, 1899) correctly draws attention to the fact that, by this manipulation, a granulating wall forms at the chiselled surface, which prevents epidermization taking place from the external meatus into the tympanic cavity.

In order to clean out the tympanic cavity, the detached posterior wall of the membranous meatus is drawn as far as possible towards the anterior wall of the auditory canal with a blunt retractor. When, in spite of this procedure, a free view of the cavum tympani cannot be obtained, the author makes several incisions into the posterior wall of the membranous meatus necessary for the plastic operation (*vide* Plastic Methods, p. 533), and has the flaps thus constructed pulled upwards and downwards by means of small, pointed retractors. From the cavum tympani, which is now completely exposed, the often necrotic and defective malleus and incus embedded in granulations and cholesteatomata, together with the remnant of the membrana tympani, are removed with a narrow, sharp curette. Curetting the cavum tympani is done in such a manner that the point of the sharp curette is passed from the promontory wall towards the external meatus, whereby the stapes is less liable to be dislocated.

After having cleaned out the tympanic cavity—care being taken not to curette the internal wall—any depressions on the floor of this cavity and in the neighbourhood of the tubal orifice are scraped out with small, lentiform curettes; this must be performed with great care, as a dehiscence in the wall of the carotid canal and jugular fossa may be present. The middle-ear spaces, now completely laid open, are again carefully examined to see if there are still any projections, depressions, and roughness of bone. In most cases a chisel and the smallest sharp curette are sufficient to smooth off the surface of the wound.

In order that the wound may take a normal course, a thorough removal of all diseased tissue is most important. The more completely the walls are smoothed off, the more uniform will be the growth of granulations. When cholesteatomata are present in the mastoid process, it is most difficult to obtain a good granulating surface. The membrane, lining the cholesteatomatous

cavity must always be thoroughly removed, as it can never be foretold whether it will not act as a matrix and cause a recurrence of the cholesteatoma. In cases of cholesteatomata of the mastoid process, Zaufal recommends, after the thorough removal of the masses with the curette, that the surfaces of the bone be cauterized with a Paquelin cautery, or painted with tincture of cantharides.

When the operation is completed, the wound cavity is cleansed by irrigating it with a warm, sterile saline solution, and then disinfected with peroxide and alcohol, or swabbing it with tincture of iodine, which is again removed with alcohol.
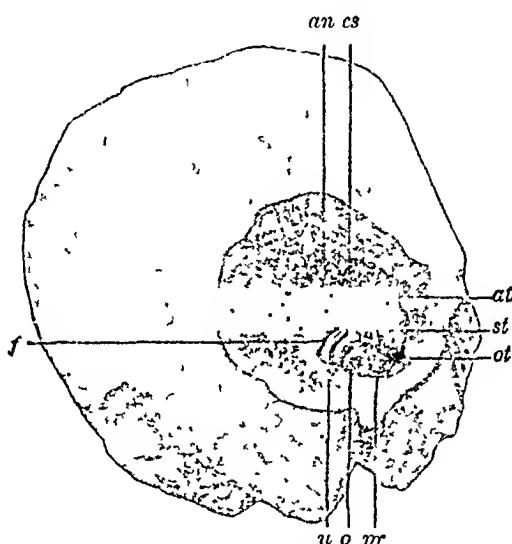
FIG. 251.—A VIEW OF THE FIELD OF OPERATION AFTER THE COMPLETE OPENING UP OF THE MIDDLE-EAR SPACES.

an, Antrum on a plane with the superior and posterior surfaces of the wound cavity; *cs*, Prominence of the horizontal semicircular canal; *at*, The opened attic; *st*, Region of the stapes; *ot*, Tympanic orifice of the Eustachian tube; *pr*, Inner wall of the tympanic cavity (promontory); *o*, Fenestra cochleæ; *u, f*, Descending part of the facial canal (artificially opened for inspection).

The size of the external opening in the planum mastoideum always depends on the extent of the disease in the bone. An opening in the bone, extending far posteriorly and inferiorly, is necessary in cases in which the antrum is markedly widened posteriorly and superiorly; such an opening is also indicated in cases in which, besides the antrum, the vertical part of the mastoid process is destroyed by caries or cholesteatomatous masses; further, when the cortical layer is pierced by fistulous openings, and when the sinus, exposed by the carious process, is covered with granulations. In a like manner the operations which are carried out for intracranial complications and sinus

thrombosis also necessitate a wider opening in the mastoid process.*

When scraping out the middle-ear spaces, it is imperative that the tympanic orifice of the Eustachian tube is also thoroughly curetted, as it is only by this means that the formation of healthy granulations and the occlusion of the tube by the formation of a cicatrix are brought about. Sometimes, in order to expose the tympanic orifice of the Eustachian tube, it is necessary to chisel away a portion of the markedly bulged, anterior wall of the meatus (Winkler, *Verb. d. deutschen otol. Ges.*, 1903). Segura† states correctly that occlusion of the tympanic orifice of the
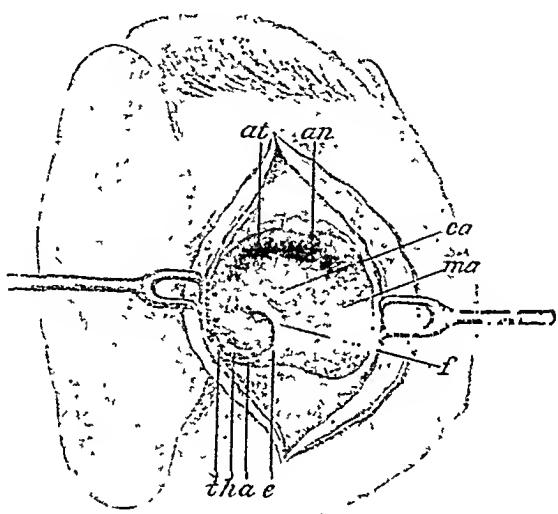
FIG. 252.—VIEW OF THE FIELD OF OPERATION AFTER THE COMPLETION OF THE RADICAL OPERATION (LEFT EAR).

at, Attic; *an*, Mastoid antrum; *ca*, Prominence of the horizontal semicircular canal; *ma*, Surface of the wound in the neighbourhood of the sigmoid sinus after removal of the mastoid cells; *f*, Facial spur; *e*, The remaining portion of the posterior wall of the cavum tympani; *d*, Neighbourhood of the sulcus tympanicus; *h*, Floor of the cavum hypotympanicum; *t*, Tympanic orifice of the Eustachian tube.

Eustachian tube after the radical operation is the most important factor in bringing about a cure and epidermization of the wound. This occlusion, however, is not always possible even after a most thorough use of the curette. In such cases the lack of closure of the tube and the continuous communication of the wound cavity with the pathologically altered mucous membrane of the tube and naso-pharynx are the main causes in bringing about repeated infections and relapses of the middle-ear conditions. According to Gerber (*Archiv f. Ohrenheilk.*, vol. lxx.), the primary transplantation of a small Thiersch skin flap over the tympanic

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* Moure, *De l'ouverture large de la caisse et de ses annexes* (*Revue hebdomad. de laryng., d'otol. et de rhinol.*, Nos. 18–20, pp. 513, 545, 577).
† Congrès intern. de Madrid, 1904.

orifice is the best method to bring about a closure of the tube after the radical operation.

One of the most unpleasant accidents when performing the radical operation is injury to the horizontal semicircular canal, which is generally recognized as a yellowish prominence in the middle of the dark red, internal, antral wall; sometimes, however, it cannot be differentiated from the parts surrounding it. In two cases operated on by the author, in which this canal was injured, there was no impairment in the hearing, but nausea, dizziness, and nystagmus, the rapid movements of which were directed to the opposite side, and lasted several days. The facial nerve is more frequently injured, and cannot always be avoided even by the most careful surgeon, owing to the abnormal course which the facial canal sometimes takes. If caution is observed when operating in the neighbourhood of the facial canal, it is but seldom that the nerve is severed in its entirety. A proof of this lies in the fact that in the majority of cases in which, immediately after the operation, a facial paresis or paralysis comes on, the condition disappears again after weeks or months. A facial paralysis which occurs only one or two days after the operation is due to an inflammatory irritation of the neurilemma, and, with but few exceptions, always passes away; the prognosis is therefore more favourable in these cases than when a paralysis arises immediately after the operation. The accidental chiselling away of a piece of the tegmen antri or tympani, with exposure of the dura mater, is, as a rule, never followed by any ill-effects. The defect produced in the tegmen must be thoroughly inspected, and ragged or sharp pieces of bone at the borders must be carefully removed, in order to prevent a pressure necrosis of the dura. Even the exposure of a non-infected sinus has no detrimental influence on the course of the wound. Slight injury to the wall of the sinus is not, as a rule, followed by any evil results, but rupture of the sinus wall is followed by a profuse hæmorrhage which requires immediate and tight tamponing, and must not be removed for five to six days.

Another untoward accident is the unintentional luxation of the stapes from the fenestra vestibuli, whereupon the suppuration extends to the labyrinth, producing a total deafness or a fatal meningitis. This ossicle is somewhat protected against injuries by the frequent absence of its crura, by its deep situation in the pelvis ovalis, and by the facial spur. In spite of this, a luxation of the stapes may take place if the tympanic cavity is not scraped in a direction from the promontory wall towards the external meatus. Regarding the serious sequelæ of the unintentional extraction of the stapes, the reader is referred to p. 489.

The radical operation is modified by certain anatomical and pathological conditions. Among these one must mention

(1) a sigmoid sinus, which is abnormally pushed forwards; when such a condition exists, it is impossible to make a large opening in the planum mastoideum. (2) A sclerosis of the mastoid process combined with obliteration of the antrum. In the latter case, even if, after a considerable amount of bone has been removed from the posterior superior wall of the meatus, the antrum cannot be opened, it is advisable to open up the middle-ear spaces by Stacke's method.

This method differs from the typical radical operation in that the tympanic membrane is exposed, the malleus with the remnant of the drum is removed, and the external attic wall is chiselled away, after the posterior, superior, and inner parts of the cartilagino-membranous meatus have been detached, and held in position with a retractor. Thereupon the incus is extracted, the protector introduced backwards into the aditus ad antrum, and so much of the posterior superior wall of the meatus chiselled away until the protector has reached the posterior boundary of the antrum. Under the continuous guidance of the protector, the bony masses still covering the antrum externally are removed, and the antrum thus changed into a trough, which forms with the attic and external meatus one common cavity. Laterally, so much of the posterior wall of the bony canal is removed that it passes over into the antrum wall in a straight line.

The typical radical operation and the method of Stacke have their fixed indications. Stacke's method is contra-indicated when there are fistulous openings on the mastoid process, when there are symptoms of intercurrent abscess formation within this bone, when strictures of the external meatus exist, and, furthermore, when there are signs of an intracranial complication. In such cases only the true radical operation should be performed. On the other hand, Stacke's method offers great advantages when the sinus is abnormally pushed forwards, and when the mastoid process is sclerosed.

The older method of the typical opening of the antrum mastoideum, as proposed by Schwartze, has been almost completely replaced by the radical operation. Schwartze and his pupils regard that the former indications for the typical opening up of the antrum still hold good in cases which are not complicated with cholesteatoma, and in which the perforation in the posterior superior quadrant of the drum is not situated at the periphery (*Archiv f. Ohrenheilk.*, vol. lvii.). The antrum is reached the quickest, according to Schwartze, Hartmann, and Bezold, at a point below the linea temporalis, at the level of the superior wall of the meatus, and about 7 mm. behind the spina suprameatum.* When this is absent, it is recommended to use, as the anterior boundary of the opening made by operation, the place where the planum mastoideum bends over into the posterior wall of the meatus, and as the upper boundary of the cavity, the upper border of the osseous meatus. Not infrequently the position of the antrum is designated by a more or less prominent hollow depression behind the superior part of the external orifice of the osseous meatus. It lies directly behind the spina suprameatum, which acts as a guiding landmark as the place of operation. In reference to the technical procedure in opening the antrum, the author refers the reader to the description under Acute Mastoiditis, p. 506.

After the antrum has been opened up, and all diseased tissue has been thoroughly removed, the wound is irrigated under moderate pressure with a sterile saline solution, whereupon the fluid escapes through the external meatus without any hindrance. The after-treatment is carried out as already described.

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* M. Yearsley, *The Constancy and Variations of the Suprameatal Spine of Henle* (Congrès int. d'Otologie, Bordeaux, 1904).

A modification of the operative method as devised by Schwartze consists in removing a portion of the posterior superior wall of the meatus and the external antrum wall, and allowing the external attic wall to remain, so as to preserve the malleus and incus. This operation, which is supposed to overcome the loss in hearing caused by the typical radical operation, however, fulfils its purpose only in a very few instances, as it is hardly possible to remove all the diseased tissue from the middle ear by this method. According to observations at the author's clinic, the suppuration continues after this operation, and when it does cease, it returns within a short time. When cholesteatoma and granulations are present in the tympanic cavity, and when there is a large perforation of the drum, the operation is from the very beginning contra-indicated. It should only be performed in those cases in which the ear to be operated upon is the only one with which the patient hears, or is the better hearing ear; furthermore, when it is important to retain the hearing on account of the occupation of the patient,* or his social position, and if there is no vital indication for the radical operation.

3. The Plastic Methods.

The so-called plastic operation of the external auditory canal, which is carried out after completion of the radical operation, prevents the development of a stricture of the meatus, and utilizes the posterior wall of the membranous meatus for partially covering the surfaces of the bone cavity. The flaps made from the posterior wall of the membranous meatus are the starting-points from which epidermization of the uncovered, granulating bone-surfaces takes place.

The plastic operation of the external auditory canal consists in the formation of flaps from the posterior wall of the membranous meatus.† It was first proposed by Stacke, and has since undergone many modifications. The choice of operation depends on whether the external incision in the skin should be closed immediately, or whether the opening in the bone should be kept open permanently, or only for the time being.

While some authors—for example, Körner, Jansen, Noltenius, and others—try to close the retro-auricular wound by primary union, others recommend that the cavity in the bone be kept open in the majority of cases. In the author's opinion, it is much better to individualize, and to decide whether it is better to close the wound immediately or to keep it open, according to the changes found in the temporal bone.

Primary union of the retro-auricular wound is indicated when we are fairly certain that all the diseased tissue has been removed, and when the loss of bone substance has not extended very far posteriorly and superiorly. On the other hand, when there are extensive cholesteatomatous masses in the temporal bone, when the antrum is markedly widened posteriorly and superiorly,

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* Cp. Schönemann, *Verh. d. deutschen otolog. Ges.*, 1906; and E. Urbantschitsch, *Monat. f. Ohrenheilk.*, 1908.

† Cp. Stacke, *Die operative Freilegung der Mittelohrräume nach Ablösung der Ohrmuschel*, etc., Tübingen, 1897.

when there is a great loss of substance in the vertical portion of the mastoid process, and when there are symptoms of intracranial complications which render the exposure of the dura or sinus necessary, it is better at first to leave the wound open. The temporary keeping open of the retro-auricular wound in these cases has the advantage of affording a better chance of observing the course of the wound, and of aiding our post-operative treatment. If the wound is taking a normal course, the retro-auricular opening can be closed secondarily by sutures, if it has no tendency to close by itself. On the other hand, the great advantage of primary union is that the post-auricular wound closes within a few days, and the after-treatment can be carried on in the out-patient department, which enables the patient to resume his work within a very short time.

We must endeavour to bring about a persistent opening behind the ear when there is an extensive collection of cholesteatomatous masses in the temporal bone, by which the greater part of the mastoid process has been destroyed, and a cavity, reaching far posteriorly and superiorly, has been formed. A persistent, retro-auricular opening enables us to remove cholesteatomatous deposits, which result from the process of epidermization, and which lie in the recesses of the cavity, with much more certainty than is possible by way of the external auditory canal. The patient is also able to wash out his ear from time to time, thus preventing the deposit of crusts and masses of epidermis. This indication is regarded too lightly by otologists. Only in cases in which, after long observation, we are convinced that desquamation in the cavity is slight, and that new deposits of epidermis can be removed as easily from the external meatus as from the cavity direct, may we close the retro-auricular wound (for appearance' sake) by one of the plastic methods.

Panse's Plastic Operation.—The posterior wall of the membranous meatus is incised at a right angle to the long axis of the auditory canal as far as the auricle (Fig. 253, *c*). To accomplish this, a strong pair of anatomical forceps is passed through the external auditory canal, and that part of the posterior wall of the membranous meatus between the branches of the forceps is cut through with a blunt-pointed bistoury up to the auricle. The incision reaches close (externally) up to the posterior edge of the external auditory orifice; only if the antrum is very much enlarged backwards and upwards, and it is desired that the external auditory orifice should be made larger so as to get a better view of the cavity in the bone, is it necessary to lengthen the incision 3–5 mm. into the concha. At the external extremity of this incision, and at right angles to it, two short incisions are made upwards and downwards (Fig. 253, *s*, *s*),' whereby two flaps are formed, an upper and lower. In order to make these flaps thinner and more movable, the soft parts on their posterior

surfaces are removed with a pair of curved scissors.   The inferior or lower flap (Fig. 254, *u*) is then sutured to the inferior angle of the wound, while the superior or upper flap (*o*) is either tamponed or sutured to the superior angle of the cavity.

In those cases in which it is desired that the retro-auricular wound should be transformed into a persistent opening, it is recommended to bring the epidermis of both meatal flaps in contact with the epidermis of the external incision in the skin.   If, on the other hand, the wound is to be closed by secondary union, an exposed raw surface should be left (Fig. 254) between the epidermis of the external incision and that of the flaps when they are fixed in position.

Staeke's plastic method is as follows: Staeke makes a longitudinal incision through the superior wall of the membranous meatus as far as the concha.
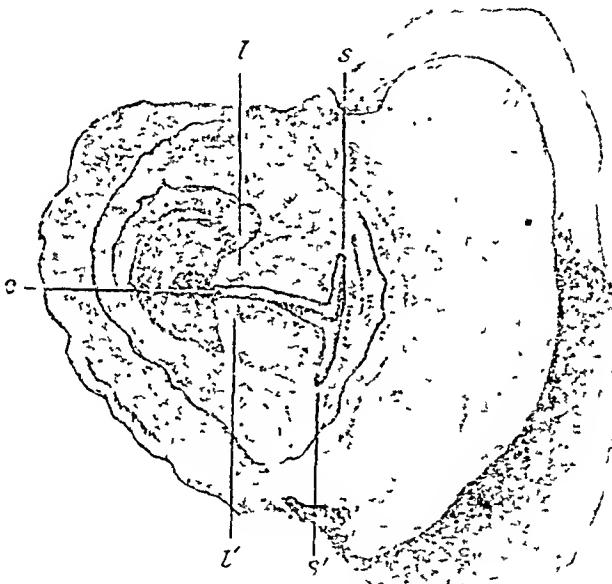
Fig. 253.

c, Longitudinal incision through the posterior wall of the membranous meatus; s, s′, Superior and inferior incisions which are made at right angles to c, where the concha passes into the auditory meatus; l, l′, Superior and inferior flaps which are made from the posterior wall of the meatus.

At right angles to this another incision is made downwards and close to the concha.   In this manner a rectangular broad flap is obtained, which is formed from the posterior and a part of the superior wall of the membranous meatus.   This flap is pressed against the inferior surface of the cavity of the wound, and kept in position by tampons.

Körner's plastic (Fig. 255), a modification of a method originally suggested by Panse, is suitable only for those cases in which it is desirous to close the retro-auricular wound by primary union. Two parallel incisions (*l*, *l′*), about a quarter of an inch apart, are made into the membranous meatus up to the concha, and even a short distance into it.   As a result of this, one large

broad flap is formed (Fig. 255, *lm*), and the external auditory orifice is so enlarged by bending back the incised cartilage of the concha that a better survey of the cavity in the bone is thereby obtained.

After the flap has been formed, the soft parts on its posterior surface are removed with a pair of scissors and the thinned flap is tamponed against the posterior surface of the bone cavity. To accomplish this more easily, the author uses a rubber drainage-tube $1\frac{1}{2}$ cm. wide, which is split in its entire length; this tube is introduced into the external meatus in such a manner that the slit is directed towards the anterior wall of the meatus, while the
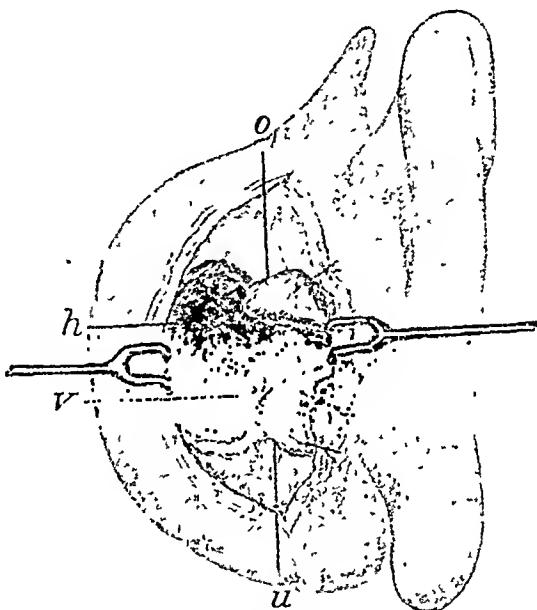
FIG. 254.

h, Posterior wall of the bone cavity produced by the operation; *o*, Superior, and *u*, inferior, flaps made from the membranous meatus, and united to the anterior edge of the wound; *v*, Anterior wall of the meatus.

meatal flap lies upon its posterior surface. After we are convinced that the flap on the tube is in the right position, the auricle is replaced and the flap tamponed through the drainage-tube by means of small, longitudinal strips of iodoform gauze against the posterior surface of the bone cavity. This simple device of applying the tampon has the advantage of not disturbing the flap when removing the gauze and drainage-tube at the first dressing; with the ordinary tampon, the flap can easily be loosened from the underlying surface when changing the gauze. After the flap and tampon are in their proper position, the retro-auricular wound is closed with sutures or with Michel clamps, and the outside dressing and bandage applied (*vide* After-Treatment, p. 543). If at the first dressing we are con-

vinced that the flap is adherent to the surface of the wound, the drainage-tube may be dispensed with at future dressings.

The **Siebenmann's plastic** (Fig. 256) consists of a longitudinal incision made in the posterior wall of the membranous meatus, which divides in the neighbourhood of the concha into the form of a **Y**, whereupon these two incisions are continued far into the concha. Three flaps are thus formed, of which the two lateral (*a* and *b*) are fixed to the upper and lower part of the wound, just as in the Panse plastic, while the central (*c*) large flap, which has been thinned down by excision of a piece of cartilage, is tamponed against the posterior surface of the bone cavity.
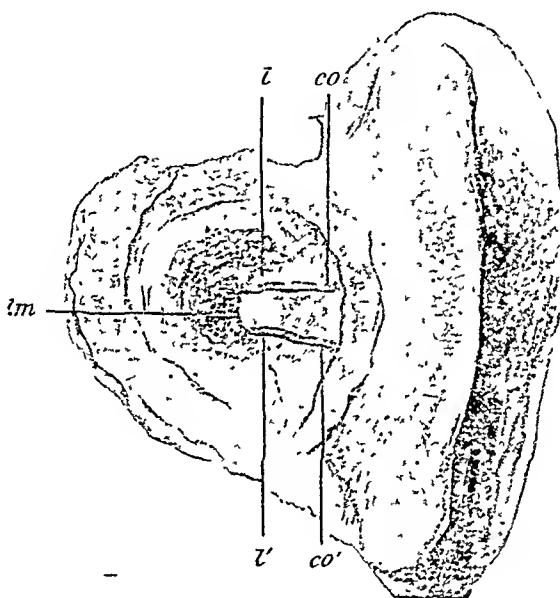
FIG. 255.

co, co'. Parallel incisions through the posterior wall of the membranous meatus; *lm*, The central flap; *l*, The superior wall of the cartilagino-membranous meatus; *l'*, The inferior wall of the same.

This plastic possesses the disadvantage that the external auditory orifice becomes too large from a cosmetic point of view. In the last few years the author has frequently used at his clinic a modification of Siebenmann's plastic as purposed by Neumann. It differs from the Siebenmann plastic in that the **Y**-shaped incisions do not extend so far into the concha, and the cartilage of the central pointed flap is not excised. In this way an external auditory orifice is produced which is sufficiently large, and does not create such a deformity.

Passow's plastic (Fig. 257) forms a large upper flap (*a*) from the medial part of the external meatus, and a short Körner flap (*b*) from the lateral part of the meatus and part of the concha. This is done in such a manner that the meatus is incised parallel to its long axis as far as the auricle (1) at the place where the posterior passes into the inferior wall. A second incision, per-

pendicular to the first, is made about ½ cm. from the lateral extremity of this first cut, and passes up perpendicularly (2) through the entire posterior and superior walls. From the upper end of this incision an incision is made forwards into the concha (3), and another backwards (4). Through the latter, the upper flap (*a*) is made movable, so that it can easily be placed against the upper wall of the bony wound cavity without obstructing the view into the deeper parts. Two catgut sutures, which are passed through the periosteum of the posterior border of the skin wound, hold the short, tongue-shaped flap (*b*) posteriorly. The base of this flap is advantageously made wider in that the incisions are made divergent into the concha. The retro-auricular wound is closed with Michel clamps.
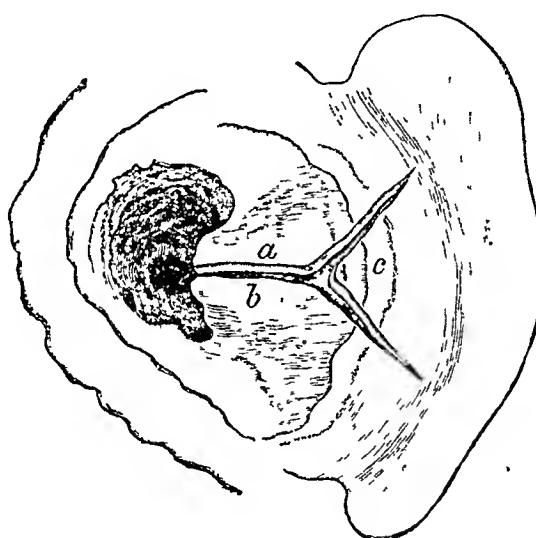
Fig. 256.

Botey's plastic (*Archiv für Ohrenheilk.*, vol. xlv.) does not injure the cartilage of the ear. He makes an anterior superior longitudinal incision through the membranous meatus as far as the incisura trago-helicina, whereby two long flaps are produced, which are fixed with sutures, or by tampon.

Blühl (*Monat. für Ohrenheilk.*, 1905) combines Panse's plastic with that of Körner (Fig. 258) in that he makes an incision for about two-thirds of the length of the posterior wall of the membranous meatus in its long axis, and makes two more incisions at right angles to this (*a* and *b*), whereby a posterior flap (*c*) is formed from the remaining part of the membranous wall and a part of the concha, which is thinned down and tamponed against the posterior surface of the wound.

Suppuration or gangrene of the flaps of the auditory canal is rare. Perichondritis, with subsequent deformity of the auricle,

may occur, but does not happen often. This complication is supposed to be due to a faulty treatment of the wound, but is brought about in the majority of cases by infection through the *Bacillus pyocyaneus*. The inflammatory swellings of the auricle subside upon the application of fomentations of Burow's solution.

The shape, size, and form of the external orifice of the ear after the plastic operation depend on how far the incisions are carried into the cartilage of the concha, and on the tamponing during the after-treatment. In cases in which the external auditory orifice shows a tendency to contract, the introduction of correspondingly wide drainage-tubes is necessary during the
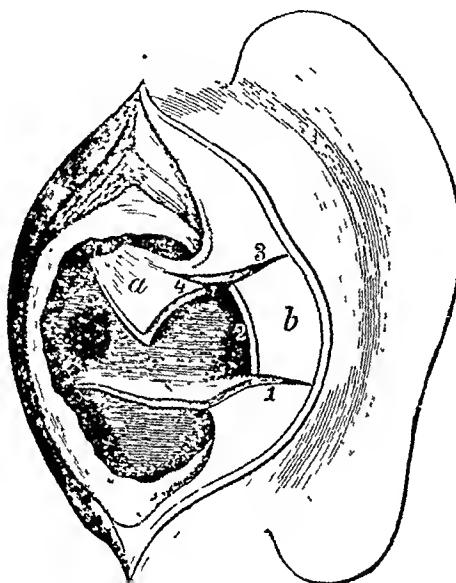
Fig. 257.

treatment of the wound. The enlargement of the external auditory orifice is not noticed if the plastic has been properly performed.

The process of epidermization of the surfaces of the wound starts from the anterior inferior wall of the auditory meatus, which has not been touched, and from the flap constructed from the posterior wall of the auditory canal. Little islands of epidermis on the promontory wall, from which, according to Hammerschlag,* the process of epidermization proceeds in different directions, are the remains of epithelium which have been left in the mucous membrane, and which, through metaplasia, assume the character of epidermis.

The endeavour to hasten the process of epidermization on the uncovered parts of the wound, and thereby shorten the

* *Wiener klin. Wochenschr.*, 1899, No. 43.

course of healing, has led to different methods whereby skin-flaps covered with epidermis, and taken from the hairless parts around the field of operation, are implanted into the wound cavity.

Kretschmann (*A. f. O.*, vol. xxxvii.), after having made a Panse plastic, makes a curved incision in the integument external to the line of the hair, and parallel to the posterior edge of the retro-auricular wound. From the middle of this incision a short connecting incision is made to the posterior edge of the wound, whereby two skin-flaps are formed, which are dissected from their bases, and implanted into the bone cavity from above and below.

Siebenmann (*Berliner klin. Wochenschr.*, 1893) makes, from the retro-auricular region, a movable flap, the apex of which is directed downwards and the base towards the line of the hair. This is dissected free, and tamponed into the cavity of the wound from above—in other words, from behind.
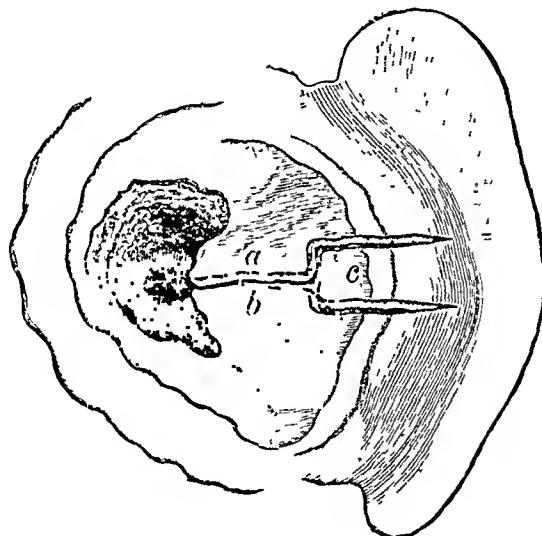
Fig. 258.

Passow (*Monographie Hirschwald.*, Berlin, 1895) makes, in order to keep the wound open, an inverted Stacke flap, which he tampons against the superior wall of the cavity in the bone. He then forms a flap from the skin of the mastoid process which is turned up, so that its original posterior edge is brought into apposition with the remains of the inferior wall of the auditory canal, where it is fixed by sutures. The original anterior edge of the flap is brought into apposition with the posterior edge of the retro-auricular wound, and fastened with sutures. The defect on the side of the neck caused by the removal of the flap is closed by bringing the two edges of the wound together with sutures. Just as in Siebenmann's plastic operation, the free wound edge of the concha is covered by uniting the integument covering the anterior and posterior surfaces of the auricle.

Stacke forms, before the radical operation, a large, tongue-shaped skin-flap, which is made only of the skin and subcutaneous cell tissue, from the parts covering the mastoid process, and the apex of which is directed downwards. A tongue-shaped flap from the periosteum of the mastoid process is now made by two incisions diverging downwards. The tegmen tympani and antri are covered by the superior skin and connective-tissue flap, and the floor of the antrum, as well as a part of the facial spur, by the periosteal flap.

A method which is occasionally practised is the transplantation of Thiersch's grafts into the cavity; this is especially recommended by Reinhard,* Jansen (*loc. cit.*), and Ballance. Jansen applies Thiersch's grafts to the smoothed-off surfaces of the wound immediately after the operation, while others recommend the transplantation of skin to the granulating surfaces which form during the treatment of the wound. If, in these cases, the graft fails to take, it is undoubtedly due to the fact that the granulating surface is not always free from infection; still, it must be mentioned that transplantation also fails even when the local conditions are most favourable, and that sometimes after a successful transplantation a destruction of the new epidermis also takes place after some time. In those cases in which the transplanted graft remains permanent, it is of great value, as it materially shortens the time of healing; without transplantation, complete epidermization takes place only after six to eight weeks, and in large wounds from two to three months or even longer.
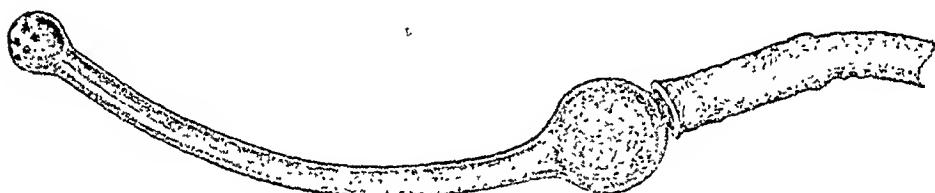
FIG. 259.

The transplantation of Thiersch's grafts must be carried out under strict aseptic precautions. Jansen transplants immediately after the operation, at different places of the bone cavity, small grafts which he covers with little pieces of gauze smeared with boracic acid ointment. The author used, as a protective to the grafts, small pieces of sterilized tinfoil.

Chas. A. Ballance's method of performing the plastic operation is different from those already mentioned. After the typical radical operation, the membranous meatus—which has been incised in its long axis—is fixed to the skin-flap which has been dissected off, and the wound is closed. Ten to fourteen days later the sutures are removed, the wound is again laid open, and the granulating wound surface is covered with large Thiersch's skin-flaps taken from the forearm.

The intra-auricular method of transplantation,† as suggested by the author, is suitable for those cases in which the retro-auricular wound is closed immediately after the operation. If the wound is taking a favourable course and is covered with healthy granulations, the operation is carried out on the sixth to the twentieth day.

Before transplantation is performed, the ear is irrigated several hours previously with sterilized water, and then filled with a peroxide solution, which is again removed with sterile cotton. Three to four hours later

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* *Versamml. deutsch. Naturf. u. Aerzte in Düsseldorf,* 1898.
† *Wiener med. Wochenschr.,* 1904.

a 1–2 square cm. skin-flap, which is as free from hair as possible, is removed with a broad, flat knife from the inner side of the leg or from the forearm.

The small flap, which has been flattened out on the knife is placed with a small forceps on the upper perforated globular end of a glass cannula (Fig. 259) in such a manner that the epidermal layer lies against the glass surface. This cannula is connected with a small air-bag by means of a rubber tube.

The transplantation of the flap is carried out in such a manner that, after removal of the sterile gauze tampon, and under full illumination of the meatus, the anterior end of the glass cannula covered with the flap is introduced through the meatus up to the granulating surface, and the skin-flap is blown on to the wound surface by compressing the air-bag. The cannula is then carefully removed from the ear, and parts of the flap which are not entirely adherent or folded up are flattened out, under direct illumination with the head mirror, by means of a probe, and made to come completely in contact with the granulating surface. The small cannulæ with globular ends (Fig. 259) are used in a broad, while the straight cannulæ (Fig. 260) in a narrow, meatus. Small sterilized cotton pledgets, which are introduced
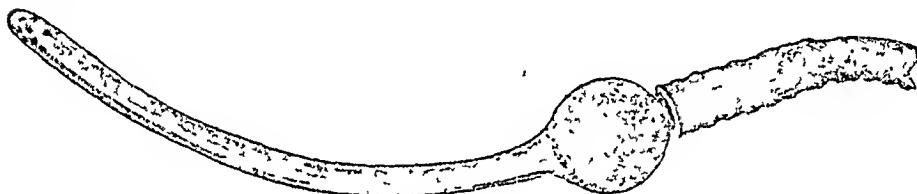
FIG. 260.

with a delicate forceps, are then pressed lightly against the transplanted grafts, and then piled up on one another until the osseous meatus is entirely filled.

Union of the transplanted skin-flap takes place from three to four days. If union has not taken place during this time, then it will not occur even if the flaps are allowed to remain longer. Union does not take place readily in the region of the tympanic orifice of the tube, which has remained open. According to the author's observations, the continuation of a moderate secretion on the granulating surface does not hinder the partial union of the transplanted graft.

4. Methods for closing Persistent Retro-Auricular Openings produced by the Radical Operation.

The Plastic Operation of Mosetig-Moorhof.*—A tongue-shaped flap, which is somewhat larger than the defect in the bone, is first drawn with a pencil below the retro-auricular opening on the skin of the mastoid process— that is, on the lateral cervical region. The flap is then dissected up as far as the edge of the defect in the bone, to which it is connected by a broad pedicle. The circumference of the opening is deepened in a furrow-like manner to the extent of 2 mm. by means of a pointed bistoury; the flap is then turned up, and after its edges have been freshened, it is brought into the furrow around the defect in the bone, and fixed by sutures. The epidermal surface of the skin-flap is thereby turned inwards—in other words, towards the wound cavity. The defect caused by the removal of the flap is closed by uniting the edges of the incision in the skin. The external raw surface of the flap may be covered

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* *Centralblatt für Chirurgie*, 1898, No. 46.

either with Thiersch's grafts, or allowed to cicatrize. In two cases the author observed, some time after cicatrization, a rich growth of hair on the inner surface of the reversed flap in the mastoid cavity.

Passow,* having first anæsthetized the parts, makes an oval incision around the edge of the opening right down to the bone. Inasmuch as he pushes the skin towards the wound cavity on the one hand, and away from it on the other, two movable skin-flaps are constructed—an internal (within the cavity) and an external (without the cavity). The internal flap is turned towards the wound cavity (invaginated), so that its epidermal surface faces inwards, whereupon the two edges of the wound are united by a single line of sutures. In like manner the external raw edges of the skin are drawn together until their freshened surfaces meet, and are then united by sutures. In order to obtain a smooth scar, small triangular pieces of skin are cut away from the upper and lower angle of the wound with a pair of scissors. This method, which has been often used at the Charité Hospital (in Berlin), has been found of practical value not only with small, but also with large, retro-auricular defects.

Alexander's plastic is as follows (*Archiv für Ohrenheilk.*, 1907): He makes an eccentric incision around the opening, forming thereby a larger anterior and a smaller posterior flap. Both are elevated from the underlying surface, turned over towards the operated cavity, and united with sutures (catgut). The skin surrounding the part is loosened up, and united over the flaps by a linear suture. The advantage of this method is that the two layers of sutures do not lie directly over each other, so that a premature tearing of the sutures is thereby avoided.

H. Frey (*Archiv für Ohrenheilk.*, lvi.) has brought about closure of the opening by subcutaneous injections of paraffin in a number of cases in which the diameter of the opening did not measure more than $1\frac{1}{2}$ cm. By injecting the paraffin into the skin the edges of the wound were brought together, thus closing the defect. Complete closure was often accomplished by subsequently cauterizing or freshening up the epidermized borders of the opening, thereby making them grow together firmly.

5. The After-Treatment.

The after-treatment is of greatest importance in the final result of the radical operation, as an uncomplicated course and a rapid epidermization of the wound can be obtained only from a careful and strictly-carried-out antiseptic treatment.

After the operation has been completed, the wound cavity is tamponed with iodoform or sterile gauze. The first tampon must be as tight as possible. By this means the secretion is reduced, and the meatal flaps are kept in apposition with the osseous walls. Having tamponed the wound, the bandage is applied.

If the patient does not complain of pain and if there are no marked fluctuations in temperature, the first dressing is not changed for five to six days. In removing the packing, which is at first somewhat painful, one must take care not to dislodge the meatal flaps, as they have not as yet become firmly united to the wound cavity.

From now on the dressing is changed every other day.

The manner in which the tampon is used depends on the condition of the wound during the course of treatment. If the

* *Z. f. O.*, 1893, p. 224.

wound cavity shows only a slight inclination towards the forma-
tion of granulations, the tampon must be applied loosely until
the entire cavity is covered with an even granulating surface.
If, on the other hand, the surface of the wound shows an inclina-
tion towards an excessive growth of granulations, it must be
checked by tamponing the wound as tightly as possible.

The beginning of epidermization is made evident by the exten-
sion of the whitish-gray lining of the walls of the auditory canal
to the granulating surface, and by the broadening out of the
implanted Thiersch's grafts. If the granulating surface does not
show any inclination to form epidermis, the process may be
hastened by the subsequent implantation of Thiersch's grafts.
The implantation of these grafts is attended with success only if
the granulating surface has been carefully washed with a steril-
ized normal saline solution. According to Denker, Thiersch's
grafts take better if the wound is not tamponed.

If the wound is running a normal course, the manner of
applying a tampon after the third or fourth week will depend on
whether we desire a persistent retro-auricular opening, or a
secondary closure of the wound. In the former case the wound
is tamponed from the retro-auricular opening until the epi-
dermis lining the cavity comes into contact with the epidermis
of the external surface of the mastoid process. In the latter case,
however, in which we endeavour to close the wound by secondary
union, the introduction of the tampon must be continued through
the external opening of the ear from the fourth week on. If the
tampon is inserted by way of the external auditory orifice before
the epidermis of the wound has reached the edge of the retro-
auricular opening, the latter will gradually become smaller and
completely close, leaving a hardly-noticeable linear scar. Little
fistulous openings, from the size of a hemp-seed to that of a pea,
are closed by cauterizing the edges with nitrate of silver, tri-
chloracetic acid, or the galvano-cautery.

When the retro-auricular wound is closed at the time of
operation, special attention must be given to those parts of the
wound which bound the antrum posteriorly and superiorly.
These parts are the last to become covered with epidermis, and,
in spite of most careful tamponing, continue to secrete and show
an inclination towards the growth of granulations long after
epidermization of the remaining parts of the wound has taken
place. Carefully curetting and cauterizing with nitrate of silver
or trichloracetic acid often lead to a cure.

After complete epidermization has taken place, the surface
of the wound appears dry and shining. Often, however, in the
lateral recesses of the cavity, and especially in the region of the
antrum, there are deposits of epidermis, or adherent brown
crusts, which, after a while, cause a relapse of the suppuration.
Patients in whom this occurs must visit their physician at

intervals of from four to eight weeks in order that he may thoroughly clean out the middle ear. To keep the wound cavity clean, we can give the patients instillations of a mixture of peroxide 5·0, aqua dest. 50·0, boracic acid 1·0, alcohol 20·0, to be used two or three times a day, or irrigations of sterilized normal saline solution if the discharge is copious or foul-smelling.

When, in spite of a most careful after-treatment, there is a fœtid secretion and a profuse growth of granulation at one or more places in the wound, it is due to the retention of carious or necrotic bone in the cavity of the wound. When the secretion is fœtid, antiseptic irrigations are indispensable, and instillations of peroxide into the wound, moist dressings of Burow's or of a 3 per cent. lysol solution (Manasse), and dusting the surface of the wound with boracic acid, dermatol, or airol all render good service. In several cases in which the tympanic orifice of the Eustachian tube was open, the discharge was stopped by washing out the middle ear through the Eustachian catheter. It is sometimes possible to favourably influence the further course of the wound by first cocainizing the granulations, removing them, and then scraping the bone with a sharp curette. In all cases in which the osseous disease extends to the deeper parts of the temporal bone which are inaccessible to the curette, or in which necrotic areas of bone appear during the course of the wound, it may become necessary to remove the diseased parts by performing a secondary operation.

Granulations which, in spite of tight tamponing, grow over the surface of the wound, should be cocainized and then cauterized with solid nitrate of silver or trichloracetic acid. Often one to three cauterizations are sufficient to produce a healthy granulating surface.

Special attention must be paid during the after-treatment to recesses in the posterior superior part of the antral region and to the growth of granulations in the region of the facial spur and horizontal semicircular canal (Stacke). Between the granulating surfaces there is only a small intermediate space, which sometimes leads to the agglutination of both surfaces, and later to the formation of connective tissue septa, with partial occlusion of the attic and antrum. Fœtid caseous secretion often collects there, which necessitates a secondary operation, with a thorough opening up of these recesses.

In the last few years the after-treatment, without tamponing, has found many adherents.* The experience gained at the author's clinic shows that in many cases epidermization of the

* Mühlen, *Zeitschr. f. Ohrenheilk.*, vol. xxxix.; Zarniko, *Deutsche med. Wochenschrift*, 1893; Eemann, *La·Presse oto-laryng.*, 1903; Schütter, *Monat. für Ohrenheilk.*, vol. xxxix.; Caboche, *Arch. int. o. Otol.*, 1904; Laurent, *Chirurgie oto-rhino-laryngologique*, Paris, 1906; Gerber, *Archiv für Ohrenheilk.*, vol. lxx.

wound does take place more rapidly by this method, but that more often an excessive secretion develops, which disturbs the process of healing and necessitates the use of the tampon.

Besides perichondritis auriculæ, eczema of the skin surrounding the wound must be mentioned as one of the disturbing complications arising during the after-treatment. The eczema caused by iodoform gauze appears mostly in children and in young females. In order to prevent this, the parts around the wound should be covered with sterilized boracic acid vaselin; if the discharge is profuse, this is repeated at each dressing. When, in spite of this, there is still a tendency towards eczema, the iodoform gauze should be discontinued and replaced with dermatol, airol, or sterilized gauze. As some patients have an idiosyncrasy towards iodoform, it is advisable, in most cases, to use plain sterile gauze only. When the secretion is foul-smelling, however, we may alternate the dressing every few days with iodoform gauze, but in no case should it be used continuously. Eczematous parts heal very rapidly by dusting them with boracic acid or dermatol. A disagreeable complication which appears during the after-treatment is erysipelas.

The facial pareses which sometimes arise in the beginning of treatment are, as a rule, due to an inflammatory irritation of the Fallopian canal and neurilemma of the facial nerve. These pareses almost always subside completely after several weeks. The prognosis of a facial paralysis which has existed some time before the operation is less favourable; still, the author has repeatedly seen such a paralysis disappear after the radical mastoid operation.

6. The Prognosis.

(a) **In Respect to Recovery.**—The final result of the radical operation depends on the extent of the osseous affection in the temporal bone, on the general condition of the patient, and on the simultaneous intracranial complications. Accordingly, the prognosis is more favourable in healthy persons, and in circumscribed non-complicated affections in the temporal bone; it is less favourable when there is caries and necrosis of the petrous bone and labyrinth, in extensive cholesteatoma, and in intracranial complications. The last mentioned are of special importance in this connection, as the appearance of severe cerebral symptoms is in itself a vital indication for the radical mastoid operation.

In the uncomplicated cases, the radical operation brings about a cure of the middle-ear suppuration in the majority of cases. The duration of the after-treatment, until complete epidermization of the wound has taken place, varies from five or six to nine months and over. The average duration varies from three to

four months. The course of the wound is slow when, in spite of a careful operation, circumscribed portions of diseased bone remain, which become covered over with granulation tissue, thereby preventing epidermization.

Such wounds, lasting for months, even years, after the radical operation, were observed by the author in the middle-ear suppurations following scarlatinal diphtheria, and in tuberculous, scrofulous, anæmic, and syphilitic individuals. The carionecrotic parts of bone which become evident during the course of the wound appear as small, irregular depressions, or as circumscribed, slate-gray islands, which feel rough on probing; they are sometimes very extensive, and cannot be detected with the naked eye, as they are often completely covered with granulations, thus preventing epidermization of the wound cavity.

Superficial, circumscribed, carious portions of bone are sometimes expelled as small bony fragments, or gradually disappear through absorption without a noticeable sequestration. Sometimes a single or repeated scraping of the profusely secreting granulations and the underlying bone is sufficient to bring about a healthy granulating surface, which rapidly becomes covered with epidermis.

The transformation of the surface of the wound into a mucous membrane covered with a layer of epithelium is one of the rare causes preventing epidermization. If one examines microscopically some of the secretion taken from the surface of the wound, one finds cylindrical and squamous epithelium which is characteristic of mucous membranes.

It is not surprising that the aural suppurations persist after the radical operation, if we take into consideration that the bone affection may extend to parts of the pyramid which cannot be removed on account of the danger of injuring the labyrinth and facial nerve. The remaining open of the orifice of the tube, or caries of the osseous portion of the tube, are also factors which aid in keeping up the suppuration in an otherwise successful radical operation.

Extensive cholesteatomata which have a tendency to relapse, and parts of which sometimes grow into the bone, also prevent complete healing of the wound. In these cases it is seldom possible to remove all the diseased tissue. But even when this is possible, the later invasion of the epidermis from the meatus and the dermoid transformation of the lining of the wound cavity cannot be prevented. If such cases are left to themselves, a relapse of the cholesteatoma within a certain time can be predicted with great probability. In patients who are discharged with a smooth, shining, cicatrized wound surface, one often finds, after weeks or months, shapeless, crust-like epidermic masses in the recesses of the middle ear, or the surface of the wound covered with a loosened, lustreless, and moist epidermis, after

the removal of which a suppurating, underlying surface, covered with granulations, becomes visible. Cases of cholesteatoma, which are discharged as cured, must be examined by the physician at intervals from four to eight weeks, in order to remove the products of desquamation which have gathered. In such cases the patients may treat themselves, by frequent irrigations and instillations, with peroxide and alcohol (peroxide 5·0, aqua dest., spirit. vini rect., āā 25·0). When the desquamation is moist, one should introduce a tampon daily until the secretion has ceased and the shining cicatricial surface has been restored.

The formation of cystic spaces which contain a brown, viscid fluid under the epidermis of the cicatrized wound is occasionally seen after complete epidermization of the wound surface. They appear as bluish, circumscribed areas, whose borders are sometimes indistinct, and often look like the shining sigmoid sinus at the posterior part of the cavity. After incising and curetting these spaces, a cure is usually obtained.

(b) **In Respect to the Function of the Organ of Hearing.**— According to the experience gathered at the author's clinic, it may be said in general that in patients in whom there is still a considerable amount of hearing, a change for the worse generally follows the operation, while, on the other hand, in patients in whom the hearing is greatly impaired there is often a marked improvement.* The prognosis is unfavourable when the Schwabach test is shortened. In a number of cases in which some hearing was still present, total deafness developed in the operated ear a shorter or longer time after a cured radical operation.

From the cases collected by Hammerschlag (1895–1897) at the author's clinic, in which the radical operation had been performed, it was shown that in the majority of cases the hearing is not influenced by the operation, and that only in a small percentage of cases a decided improvement, more often, however, a change for the worse, is observed. In the majority of cases, however, the hearing is diminished, if the labyrinth is simultaneously involved. It is, therefore, essential that in every case of chronic otorrhœa in which the radical mastoid operation is performed to impress upon the patient the possibility of losing his hearing and even of becoming totally deaf.

The degree of disturbance of hearing after the operation depends essentially on the amount and tenseness of the scar tissue in the recesses of the labyrinthine windows. If the stapes is embedded in a mass of scar tissue filling the recess of the oval window, or if the niche of the round window is covered with

* According to Ruttin, if there is a hearing distance from 1½–2 m. before the operation, no change for the worse is to be expected, while if there is a greater hearing distance, it is generally reduced to this limit after the radical operation. According to his investigations, carried out at the author's clinic, the hearing distance also varies in the stage in which the wound cavity becomes lined with granulations, and not to any extent in the stage of complete epidermization.

connective tissue, the hearing will be markedly affected, inasmuch as these changes act as a hindrance to the propagation of sound. In a number of cases a marked improvement in the hearing is obtained after a cured radical operation by occasional pneumo-massage, and by the introduction of a small ball of cotton soaked with liquid vaselin against the fenestra vestibuli (ovalis). Several times a decided improvement was observed after synechotomy of the crura of the stapes. Finally, the author would like to mention that after the radical operation the general condition of the patient is often greatly improved, and that at times neuroses are greatly benefited (hysteria, chorea). In contradistinction to this, we have the observations of Grossmann (*Zeitschr. f. Ohrenheilk.*, vol. xlix.), who observed the development of psychoses (1:500) after mastoid operations. The radical operation should be undertaken as a last resort, especially in those cases in which all local measures have proved of no avail, and in which symptoms of labyrinth involvement or signs of a meningeal or cerebral complication have become evident.

Intracranial Diseases of Otitic Origin.

Introduction.

Reference has been made in previous chapters to the danger of chronic suppurations of the middle ear extending to the cranial cavity and to the sinuses of the dura mater. The thin osseous walls, which often contain dehiscences, and which separate the purulent middle ear from the dura mater and sigmoid sinus, the canals which contain bloodvessels and nerves, and run from the temporal bone to the cranial cavity, and the numerous anastomoses of the blood and lymphatic vessels, are the channels by which suppurations in the middle ear are conveyed to the cranial cavity.

The parts of the temporal bone through which the suppuration most frequently perforates towards the cranial cavity (middle cranial fossa) in chronic middle-ear suppurations are the tegmen tympani and the roof of the mastoid antrum. The osseous lamella is either perforated by an aperture the size of a pin's head, or by a number of small openings in a sieve-like manner; or a jagged perforation is formed owing to carious destruction of the larger part of the tegmen tympani and the roof of the mastoid antrum, through which pus or cholesteatomatous masses force their way from the middle ear into the cranial cavity.

In other cases perforation takes place at the posterior surface of the petrous portion of the temporal bone into the posterior cranial fossa. In such cases the suppuration makes its way through the pneumatic cell-spaces which completely surround the labyrinthine capsule towards the posterior surface of the pyramid, and brings about a deep-seated extradural or cerebellar abscess. A fistulous canal sometimes runs from the tympanic cavity behind the semicircular canals, and ends, on the posterior surface of the pyramid, in a cerebellar abscess.

The paths by which the middle-ear suppuration can extend to the cranial

cavity are: the canalis petroso-mastoideus, which is not always obliterated, the canalis facialis, the two labyrinthine windows with the aquæductus vestibuli, and the nerve canals running from the cochlea into the internal auditory canal.

Finally, the suppuration may extend, with or without carious perforation of the osseous wall, to the sigmoid sinus, less often to the superior and inferior petrosal sinuses, and to the bulbus venæ jugularis, causing a fatal sinus phlebitis.

Labyrinthine suppuration is one of the most frequent causes of intracranial complications arising from the temporal bone; its significance in otitic meningitis and brain abscess will be discussed in the following paragraphs.

Labyrinthine Suppurations.

During the last few years our knowledge of labyrinthine suppurations has been greatly augmented by innumerable anatomical, pathological, and clinical investigations, so that we are now better able to combat these dangerous middle-ear complications. Jansen deserves the credit, based on clinical and operative experience, of having called attention to these conditions, which are of such vital importance in otological practice (*Archiv für Ohrenheilk.*, vol. xlv.).

The purulent labyrinthine inflammation arising in the course of an acute middle-ear suppuration is observed more often in the scarlatinal-diphtheritic than in the primary otitis.

Rupture of the pus into the labyrinth during an acute middle-ear suppuration takes place most frequently through the fenestra vestibuli (Jansen), less often through the fenestra cochleæ (Friedrich), or through a fistula in the horizontal semicircular canal. Rupture through the labyrinthine windows produces an empyema of the labyrinth; when there is an acute fistular formation in the semicircular canal, the labyrinthine inflammation may, as observations at the author's clinic have shown, remain localized in the region of the fistula.

There is no doubt, however, that in cases in which there is no direct rupture of the pus into the labyrinth, an inflammatory affection may be produced in the labyrinth (the labyrinthitis serosa described by Alexander, *Archiv f. Ohrenheilk.*, vol. lxviii.) by the invasion of micro-organisms, or toxic infection, the symptoms of which correspond to those of a labyrinthine suppuration, which has been brought about by the breaking through of the pus. This is shown by those cured cases in which the hearing soon returned to normal after the labyrinthine symptoms had disappeared. The labyrinthine suppuration arising during a primary otitis is a rare affection. It is more frequent in scarlatinal diphtheria, with or without a middle-ear suppuration, and is that form which is so important in producing deaf-mutism.

Suppurative infection of the labyrinth occurs much more often

in the chronic middle-ear suppurations. In these cases, it is in particular the cholesteatoma (Kümmel), the tubercular middle-ear suppurations, and the sepsis brought about by the pus retention in neglected cases, which lead to rupture of the labyrinthine capsule.

The places of rupture are: (1) The fenestra vestibuli; (2) the fenestra cochleæ; (3) fistulæ in the horizontal, less often in the posterior semicircular canal; and (4) fistulous perforations in the promontory wall.

Of these, fistulæ in the horizontal (external) semicircular canal and of the fenestra vestibuli were most often observed; still, as the pathological-anatomical investigations of the author show, destruction of the fenestra cochleæ occurs more often than was formerly supposed, a condition which was also confirmed by Lange at Passow's clinic.

A suppurative infection of the labyrinth by way of the facial canal (Grunert and Dallman) is just as rare as rupture of the pus into the labyrinth from an extradural abscess (Jansen, Habermann). Gradenigo reports the extension of the suppuration through the hiatus subareuatus.

Labyrinthine suppurations are divided into circumscribed and diffuse. The former are localized most frequently in the horizontal semicircular canal, less often in the cochlea. Circumscribed inflammations of the labyrinth may, however, become diffuse by spreading over the entire labyrinth after an acute exacerbation of a middle-ear suppuration, or after operative measures (polyp extraction, radical mastoid operation).

Pathological Changes in Labyrinthine Suppuration.

The pathological anatomy of labyrinthine suppuration was enriched during the last decade by numerous interesting findings, which have been extensively reported by many authors, and especially by Manasse, Habermann, Panse, Friedrich, Alexander, Brieger, Goerke, Scheibe, Lange, and others.*

During the last years, the abundant material at the author's clinic gave him excellent opportunities to study the pathology of labyrinthine suppuration. The important data of his findings are briefly as follows:

The changes in the mucous membrane of the middle ear occurring in these processes are described on p. 377 of this text-book, and in the *Archiv f. Ohrenheilk.*, vol. lxv. Ruttin (*Archiv f. Ohrenheilk.*, vol. lxxii.) gives a

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* In the older literature we find mention of only a few cases of labyrinthine suppuration, as, for instance, in Itard's *Traité des maladies de l'oreille et de l'audition*, 1821; Alex. Platner, *De auribus defectivis, Diss. inaug.*, 1838; Toynbee, *Krankh. d. Gehörorgan*, in German, by Moos, 1863, p. 381. Compare Politzer, *Geschichte d. Ohrenheilk.*, vol. i., p. 421, and *Archiv f. Ohrenheilk.*, vol. lxv.

detailed description of cyst formations which often appear in the mucous membrane.

The changes in the labyrinthine capsule, and in the spongy tissue surrounding it, are most strikingly seen in the promontory wall. It appears denuded on its lateral side (Fig. 261, *er*), or destroyed to a small remnant, displaced and embedded in the thickened mucous membrane, or perforated by fistulæ at one or more places.

FIG. 261.—FROM A WOMAN, 40 YEARS OF AGE, WHO HAD A RIGHT-SIDED, CHRONIC, FŒTID, MIDDLE-EAR SUPPURATION SINCE CHILDHOOD.

Headache, moderate fever, total destruction of the membrana tympani; Weber to the left; Schwabach shortened. Deafness for speech. Death through meningitis. Section through the tympanic cavity and vestibule. *nl*, Masses of granulations filling the niche of the fenestra vestibuli; *st*, The remains of the stapes embedded in the granulations; *pr*, The denuded promontory; *pr'*, A fragment of the promontory in the hypertrophied mucous membrane; *nr*, Granulation masses forcing their way through the destroyed membrana fenestra cochleæ into the vestibule; *ls*, Beginning of the lamina spiralis which has been perforated; *p*, Purulent exudate and pigment patches in the vestibule; *f*, Facial canal which has been opened by destruction, through the formation of lacunæ.

The bone in the neighbourhood of a fistula of the semicircular canals always shows inflammatory changes. The fistula itself is covered with granulations or cholesteatoma. The semicircular canal contains pus or granulation tissue, which is confined to the region of the fistula, or communicates with diffuse granulations in the labyrinthine cavity. The statements of Friedrich that the fistular formation can also take place from within the semicircular canal

outwards, can be verified by the case observed by the author, in which the
superior semicircular canal was perforated at its cupula by way of the laby-
rinthine cavity, and caused an abscess of the temporal lobe, which ran a fatal
course. Frequently the horizontal portion of the facial canal is also destroyed
to a varying extent.

Isolated areas of destruction in the capsule of the cochlea, and in the adja-
cent spongy tissue, have frequently been found by the author as irregular
cavities, which were bounded by denuded borders (Fig. 262, *la* and *la'*, and
Fig. 263, *l*, *l'*), and which contained spindle-celled connective tissue grouped
around a large bloodvessel.
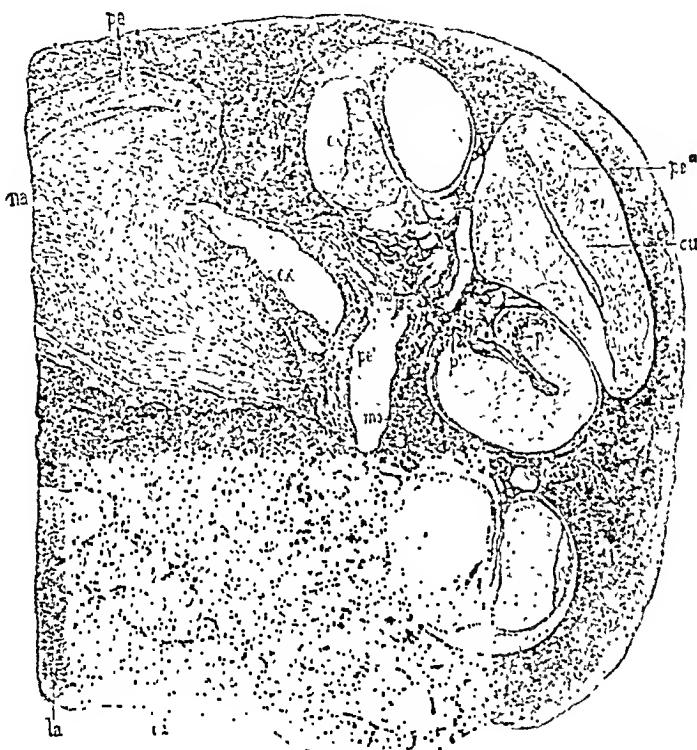
Fig. 262.—Section through the Cochlea and Internal Meatus of
the Same Case.

mo, Upper remnant of the destroyed modiolus; *cx'*, *cx''*, Purulent exudate in the
first turn of the cochlea; *pe*, Fibrillar tissue in the upper turn of the cochlea,
infiltrated with pigment; *na*, Normal portion of the acoustic nerve; *ex*, Peripheral
portion of the auditory nerve which has been destroyed by the suppuration, and
which is bounded by a line of demarcation from the central portion; *la*, *la'*, A
ragged bony defect in the spongy layer of the labyrinthine capsule, brought about
by destruction through the formation of lacunæ.

Extensive loss of tissue is found in both labyrinthine windows. The
annular ligament of the foot-plate of the stapes is perforated here and there,
or destroyed entirely; the crura are broken, and the foot-plate is partly gone,
being embedded in exudate or hypertrophied mucous membrane and dis-
located, and, as in one case, pressed against the medial wall of the vestibule
by granulations which forced their way into the vestibule.

The membrane of the fenestra cochleæ is found covered with hypertrophied,

cystic mucous membrane, thickened, broken through, or entirely absent (Fig. 261, *nr*).

The changes in the interior of the labyrinth were varied. Sometimes only a slight layer of exudate was visible on the inner surface of the foot-plate of the stapes. More often, however, the greater part of the vestibule and the semicircular canals was filled with pus, a hæmorrhagic exudate, or with a vascular granulation tissue, which was already organized in parts, and which was in communication with the hypertrophied mucous membrane of the

FIG. 263.—LEFT-SIDED CHRONIC MIDDLE-EAR AND LABYRINTHINE SUPPURA-TION IN A PERSON 17 YEARS OF AGE. SECTION THROUGH THE COCHLEA AND THE PERIPHERAL PART OF THE INTERNAL MEATUS.

me, Peripheral part of the acoustic nerve, which has been destroyed and replaced by granulation tissue; *mo*, Destroyed basilar portion of the modiolus filled with granulation tissue; *co, co'*, First turn of the cochlea, containing pus and granulation tissue, and irregularly widened through absorption of the bone; *co', co'''*, Axial portion of the cochlea still preserved in the second and last turns; *e, e'*, Purulent exudate in the second turn of the cochlea; *l, l', l''*, A loss of substance in the labyrinthine capsule brought about by absorption through the formation of lacunæ.

tympanic cavity through the window of the vestibule or cochlea, or through a fistula in the promontory wall. Cholesteatoma in the middle ear sometimes forces its way into the labyrinthine cavity.

In the cochlea, a purulent exudate is found between the membrane of the fenestra cochleæ and the beginning of the lamina spiralis. The lamina spiralis

is thickened or perforated (Fig. 262, *cx*, *cx'*, and Fig. 263, *e*, *e'*). The wall of the cochlear canal and the lamina spiralis are covered with a purulent or hæmorrhagie, pigmented exudate, or entirely filled with it.

Extensive changes sometimes develop in the interior of the labyrinth through destruction of the bony walls, which starts in the labyrinthine cavity. The osseous mass which separates the semicircular canals is destroyed in such a manner that it forms, with the vestibule which has become enlarged through absorption, a large cavity, which is filled with pus and granulations,

Fig. 264.—Section through the Cochlea of an 18-year-old Person, who had a Chronic Middle-Ear Suppuration. Death from Meningitis.

Section through the lower part of the cochlea, which has entirely been destroyed and replaced by granulation tissue, *b*, *b'*; *co*, Remnant of the basilar turn of the cochlea; *mo*, Remnant of the modiolus; *c*, New-formed bony ridges at the periphery of the cavity; *bi*, The small-cell, infiltrated, central part of the acoustic nerve; *na*, Peripheral part of the auditory nerve, which has been replaced by granulation tissue. Total deafness. (The result of the hearing tests, given in the *Archiv für Ohrenheilk.*, vol. lxv., p. 167, is not correct.)

and the borders of which extend to the thinned surface of the pyramid. The walls of this cavity are formed by numerous small, new-formed ridges, in which an osteoblastic elevation is visible.

Similar loss of substance by absorption is observed in the capsule of the cochlea and in the modiolus. The destruction advances here so far that

only a small ridge of one of the turns and a small fragment of the modiolus of the cochlea remain in the cavity, which is formed by the destructive process, and which is filled with pus and masses of granulation (Fig. 264, *co*).

Through destruction of the first turn of the cochlea and the tractus spiralis foraminulentus, the pus works its way into the internal auditory canal. When the base of the cochlea appears intact, the pus goes along the sheaths of the nerve into the internal meatus. Its peripheral end appears considerably enlarged through destruction of its bony walls, and is in communication with the space in the cochlea which has been formed by the destruction of the modiolus (Fig. 262, *mo ;* and Fig. 263, *mo*).

The auditory nerve is infiltrated with pus at its peripheral part, contains a hæmorrhagic exudate, or is displaced by the formation of connective tissue. Several times the peripheral part of the nerve, infiltrated with pus, was sharply defined from the central portion by a distinct line of demarcation (Fig. 262, *ex*). Infiltration, decomposition, and fatty degeneration were also observed in the branches of the auditory nerve, in the cochlea, and in the ganglion spirale.

In the canalis cochlearis, Reissner's membrane was covered with exudate, and Corti's membrane was destroyed. Corti's organ was always so changed that the parts could no longer be distinguished histologically. Where the sequestrated labyrinth was removed by operative measures, the cavity thus formed was filled up with fibrous connective tissue.*

Symptoms.—Labyrinthine suppuration develops in acute otitis, especially in the primary forms, with active, violent symptoms. In chronic middle-ear suppurations, it often exists in a latent state without symptoms. During an acute exacerbation of the chronic middle-ear suppuration, however, violent symptoms may suddenly arise. The symptoms of acute labyrinthine suppuration become manifest as an irritation, or impairment of the nerve apparatus. The symptoms of irritation arising from the vestibular apparatus are characterized by dizziness, spontaneous nystagmus, disturbances in equilibrium, and occasional vomiting, while those from the cochlear apparatus become evident through subjective noises. The disturbance in hearing arising with symptoms of irritation rarely appears suddenly, but develops more or less rapidly, reaching a marked degree of hardness of hearing up to total deafness.

Violent labyrinthine symptoms arising during the course of chronic middle-ear suppurations are observed when the pus ruptures into the labyrinth spontaneously, after intratympanic operative measures, or as a result of injury to the labyrinth. The symptoms, which are very severe at first, subside in their intensity, in acute as well as in chronic middle-ear suppurations, during the further course of the affection, in that the dizziness, nystagmus, and subjective noises disappear, and the existence of a labyrinthine suppuration can be established only by a careful functional examination. Of the symptoms, the marked dizziness, subjective noises, and the spontaneous nystagmus are the first to disappear, while the disturbances in

* Cp. *Labyrinthhef. bei. chrön. Mittelohreiterungen. Archiv für Ohren-heilk.,* vol. lxv.

equilibrium, especially with closed eyes, and jumping on one leg (v. Stein, Congrès de Bordeaux, 1904) and the abnormal unsteadiness in gait (called by v. Stein ' Ichonogramme ') continue.*   In the great number of chronic cases observed at the author's clinic, in which the autopsy usually revealed a diffuse labyrinthine suppuration, there were seldom violent labyrinthine symptoms at the time the patient was admitted, but only disturbances in equilibrium and slight nystagmus, which were elicited by careful examination.   It often happened that there were no subjective symptoms, except a marked degree of hardness of hearing or deafness.   When, during further observation of the patient, post-operative symptoms arose, they were soon overshadowed by the more prominent symptoms of a beginning meningitis. In the diffuse labyrinthine suppuration which leads to total destruction of the labyrinth, symptoms of irritation arising from here were usually absent.   Still, dizziness and disturbances in equilibrium may persist in spite of total destruction of the internal ear, as the observations of Hinsberg, Barnick, Körner, and others show.

Of the labyrinthine symptoms, special attention must be paid to the nystagmus.   Its various forms may change during the time that the patient is under observation.   Thus, a horizontal nystagmus may change over into one of rotation and oscillation. Spontaneous nystagmus occurs in every form of labyrinthine suppuration, but more frequently, however, in the acute form. As a rule, it appears only when looking towards the healthy side.

The nystagmus produced by rapidly rotating the body sometimes shows, in unilateral labyrinthine suppuration, a change from the normal (Wanner). Still, as Krotoschiner has demonstrated, a physiological nystagmus can also be observed with labyrinthine suppuration.   Rotatory dizziness is seldom produced in labyrinthine suppurations.   v. Stein is supposed never to have observed it in unilateral affection.   According to Scheibe and Brieger, nystagmus is absent in tubercular labyrinthine suppuration.

The disturbance in hearing, which is accompanied by active labyrinthine symptoms, attains a high degree within a few days in the acute cases, even if the circumscribed inflammation is localized in the region of the fistula.   Diffuse suppuration, extending over the entire cochlea, is associated with total deafness.   The functional examination shows a loss of perception for the tick of the watch placed against the temporal region on the side of the diseased ear, lateralization of the C^2 tuning-fork towards the opposite side, a shortened Schwabach, and total deafness for speech.

In cases of chronic labyrinthine suppuration in which there are circumscribed areas of inflammation in the labyrinth, there may still be some perception by air conduction, perception for

* Cp. Herzfeld, *Berliner klin. Wochenschr.*, 1901, No. 35.

speech to a varying degree, and Weber may be lateralized towards the diseased ear with a simultaneous shortened Schwabach. The last symptom was found in quite a number of cases observed at the author's clinic in which there was total deafness for speech. The deafness for speech is, however, no indication of total deafness, as the tone of the C^2 tuning-fork may still be perceived by air conduction in some instances. An absence of perception for the a^1 tuning-fork is indicative of total deafness.

The temperature, even in the acute cases, seldom reaches above 38° to 38·4° C. (100·5° to 101·1° F.). In the latent chronic labyrinthine suppurations it is usually absent. Higher elevations of temperature up to 40° C. (104° F.) are indicative of a beginning intracranial complication.

To the symptoms of labyrinthine suppuration which are also of diagnostic importance we must add the appearance or absence of symptoms of labyrinthine irritation brought about by condensation or rarefaction of the air in the external meatus, or by thermic irritation.

If dizziness and nystagmus are produced by condensation of the air in the external meatus (p. 137), we know that the vestibular apparatus is capable of being stimulated. This has been termed the 'fistular symptom.' This symptom can, however, also be elicited without the presence of a labyrinthine fistula by increased pressure on the labyrinthine windows. An absence of the vestibular symptoms of irritation during this test does not by any means allow one to assume that the vestibular apparatus is destroyed.

We are better able to ascertain the capability of stimulating the vestibular apparatus by the injection of cool and warm (above the body temperature) water into the meatus (see p. 89), as suggested by Barany (*loc. cit.*). If, during these manipulations, in which the thermic irritation acts upon the promontory wall, dizziness and nystagmus are produced, we can assume with certainty that the vestibular apparatus still responds to irritation; if these symptoms do not arise, it can be assumed with great probability that the vestibular apparatus is totally or partially destroyed, as Barany's experiments carried out at the author's clinic have shown. An analogous result is obtained when testing with the galvanic current by means of the voltaic alternatives (see chapter on Neurosis of the Acoustic Apparatus).

Course and Terminations.—The labyrinthine suppuration complicating an acute otitis may, as cases of Scheibe and others show, end with a fatal basilar meningitis through extension of the process from the cochlea to the internal auditory canal. A cure with a restitution of the hearing power has been repeatedly observed. Three typical cases at the author's clinic, in which a fistula in the horizontal semicircular canal was found after the mastoid and antrum had been freely laid open, recovered com-

pletely. In the scarlatinal-diphtheritic panotitis, less often in the primary forms, marked hardness of hearing or deafness remains as a result of connective tissue and bone formations. Labyrinthine suppuration not infrequently ends in caries, necrosis, and sequestration of the labyrinth, and mainly in the scarlatinal-diphtheritic forms; this, as a rule, takes place only in the chronic stage of the middle-ear suppuration.

The course of the labyrinthine suppuration in the chronic middle-ear processes is, in contrast to the violent character of the acute form, a more protracted one. Striking labyrinthine symptoms arise during an acute exacerbation of the middle-ear suppuration or after operative manipulations in the ear (polypi extraction).

Sometimes, only from the history of the case, are we able to obtain data which show that the labyrinthine symptoms are of recent origin and just beginning to develop. In the chronic forms there may be a spontaneous recovery through the new formation of connective tissue, which prevents the pus from entering the cranial cavity. This termination—most frequently observed in the scarlatinal-diphtheritic, less often in the tubercular middle-ear suppurations—is, however, brought about only through favourable local (free discharge of the secretion) and constitutional conditions.

In many cases, chronic labyrinthine suppuration ends fatally, owing to a cerebral complication. Death results most frequently from a meningitis purulenta or serosa (Jansen), owing to the extension of the suppuration in the cochlea through the internal meatus. The next most frequent cerebral complications are cerebellar abscesses (Neumann, Okada), and the temporal lobe abscesses, brought about by a fistulous perforation of the superior semicircular canal (Politzer, Hinsberg, Alexander). Combinations of labyrinthine suppuration with meningitis and cerebellar abscess, or sinus thrombosis, have been frequently reported. In a case at the author's clinic recovery took place after the operative removal of the necrotic sequestrated labyrinth through obliteration of the loss of substance by the formation of connective tissue; yet several months later death ensued in consequence of a tubercular meningitis.

To the rare cerebral complications arising from the labyrinth, we must add that form of suppuration which is transmitted from the vestibule to the aquæductus vestibuli and its intradural sac, and which may end fatally through a meningitis purulenta or serosa (Jansen) and cerebellar abscess. According to Friedrich, infection of the cranial cavity can also be brought about by extension of the suppuration through the aquæductus cochleæ.

Diagnosis.—The diagnosis of acute labyrinthine suppuration is difficult, as other changes in the labyrinth, which also have the power of subsiding, can produce the same symptoms. When distinct cerebral symptoms are absent, we can conclude with

probability that there is an acute labyrinthine suppuration only when the above-described labyrinthine symptom-complex is taken in connection with the positive result of the functional examination. The diagnosis becomes more probable if labyrinthine symptoms, with progressive hardness of hearing or marked deafness, develop while the patient is under observation. An important diagnostic symptom of a developed labyrinthine affection is the lateralization of the C^2 tuning-fork towards the better-hearing ear, when the previous examination showed a lateralization towards the diseased ear.

The diagnosis of chronic labyrinthine suppuration is often confronted with difficulties. Labyrinthine symptoms alone do not justify the assumption of localized suppuration in the labyrinth, because marked labyrinthine symptoms may also be produced by a temporary labyrinthine irritation arising from the middle ear. In a like manner, too much reliance cannot be placed on the complete deafness of the diseased ear in making a diagnosis, because, as Kümmel correctly states, such a deafness may have been produced by other secondary changes in the labyrinth which have previously existed.

The diagnosis of chronic labyrinthine suppuration can be made with certainty from the labyrinthine symptoms if taken in conjunction with the objective result of the functional examination of the vestibular and cochlear apparatus, and with the anatomical conditions found at the radical operation.

The diagnosis is made with more probability if, after excluding a cerebral complication, the functional examination reveals total deafness, lateralization of the Weber test towards the opposite side, a shortened Schwabach, in addition to marked labyrinthine symptoms. The author considers the Schwabach test of special diagnostic value. The statements of the patient of former attacks of dizziness, nausea, and disturbances in equilibrium, substantiate the diagnosis. This is made absolutely certain if, in addition to the results of examination described above, a carious area or fistula is found at the semicircular canal or at another part of the labyrinth when performing the radical mastoid operation.

Although it is possible, in a number of cases, to positively establish the diagnosis of a labyrinthine suppuration, yet actual data are still lacking, which would indicate, in cases in which there are no apparent symptoms, that a rupture of the pus in the cochlea into the internal meatus has taken place. That such ruptures can exist a long time prior to the meningeal infection can be seen from several anatomical conditions found by the author (*Archiv für Ohrenheilk.*, vol. lxv.), in which there was, in addition to the carious perforation of the base of the cochlea, a destruction of the compact bony wall of the internal meatus due to the formation of lacunæ, with a demarcated suppuration of the

peripheral end of the auditory nerve; these conditions are of great importance in establishing the indications of an operative opening up of the labyrinth.

The differential diagnosis between acute labyrinthine suppuration and other non-suppurative conditions which run their course with labyrinthine symptoms, and are capable of subsiding (hyperæmia, increased labyrinthine pressure, para-labyrinthitis, v. Stein; labyrinthitis serosa of Alexander), is very difficult in the active stage, and can often be decided only during the observation of the patient after the symptoms of irritation have passed away. Hinsberg reports a case of middle-ear catarrh, in which the symptoms of an acute labyrinthine suppuration disappeared twenty-four hours after paracentesis. We must add here the symptoms occurring with cholesteatoma, which simulate those of a labyrinthine suppuration, and which disappear after removal of the epidermic masses from the middle ear,* and also the marked temporary labyrinthine symptoms which arise during the course of an acute otitis media (Riou-Kerangal, Hinsberg).

The differential diagnosis is rendered difficult in some cases between a labyrinthine suppuration and cerebellar abscess, especially as the latter is often caused by the labyrinthine process. The statements of Körner that disturbances in equilibrium are very rare with cerebellar abscesses cannot be corroborated by the author.

Spontaneous nystagmus is of vast importance in the differential diagnosis between labyrinthine suppuration and brain abscess, for experience shows that this is produced when the patient looks towards the healthy side in labyrinthine suppuration, towards both sides in cerebellar abscesses, and sometimes more marked towards the affected side in the latter disease. According to Neumann, one may conclude that there is a cerebellar abscess if the nystagmus which is at first elicited when the patient looks towards the healthy side changes over to a nystagmus towards the affected side, or if after opening up the labyrinth the nystagmus still continues for some time. According to Alexander (*Monat. für Ohrenheilk.*, 1906), an intensive, horizontal, spontaneous nystagmus and disturbances in equilibrium point towards a cerebellar abscess. In reference to the disturbances in equilibrium, the cases examined by Alexander at the author's clinic show that in unilateral labyrinthine affection the patient is more inclined to fall towards the healthy side, while in cerebellar abscess he has a tendency to fall towards the diseased side. As an important symptom in the differential diagnosis, we must mention the choked disc which is observed with cerebellar abscesses, and which is absent in labyrinthine suppuration. The symptom-complex observed by Adler (*Archiv für Ohrenheilk.*,

* Cp. Politzer, *Wiener med. Wochenschrift*, 1891; Hennebert, *Arch. intner. d. laryngologie*, 1907, No. 1.

vol. xliii.), whereby dizziness, vomiting, and occasionally an acceleration of the pulse are produced in labyrinthine affections when the patient is placed on the affected side, and, on the other hand, in cerebellar abscesses, when the patient is placed on the healthy side, could be confirmed in a number of cases at the author's clinic.

The differential diagnosis is also rendered difficult at times between labyrinthine suppuration and meningitis if the latter takes its origin from the labyrinth, and if the purulent infection of the meninges which is produced without marked symptoms becomes localized at a circumscribed area in the posterior cranial cavity. In such a case, only the lumbar puncture establishes the diagnosis (see chapter on Meningitis). It is only when a rise in temperature, marked headache, vomiting, and contraction of the muscles of the neck arise in conjunction with the labyrinthine symptoms that the diagnosis of meningitis is established. According to Friedrich, the nystagmus and disturbances in equilibrium arising at the beginning of a meningitis indicate that the inflammation of the meninges has taken its origin from the labyrinth.

Prognosis.—The prognosis of an acute labyrinthine suppuration arising from the middle ear is not unfavourable. Many cases recover with a return of the hearing function. That form of labyrinthine suppuration described by the author under the term of panotitis (see Affections of the Labyrinth) and the scarlatinal-diphtheritic middle-ear processes running their course with necrosis and sequestration of the labyrinth often recover with total deafness. In the chronic forms, the prognosis is most unfavourable in the tubercular purulent processes, and in the infectious middle-ear suppurations associated with cholesteatoma. Brieger and Herzog report recovery in cases of tubercular labyrinthine suppurations (*Deutscher Otologentag*, 1906). The experiences at the author's clinic are unfavourable, in so far that even those cases which have stood the labyrinthine operation well, died later of phthisis or a tubercular meningitis. The result obtained by operative measures is more favourable if, at the time of the operation, no labyrinthine symptoms are present.

Of the defects found in the bony labyrinth when opening up the middle-ear spaces, the fistulæ in the horizontal semicircular canal offer the most favourable prognosis, in so far as an inflammatory area often develops in the semicircular canal before the formation of the fistula, which leads to the formation of a wall of granulation tissue and to closure of the semicircular canal, whereby the extension of the pus towards the vestibule is prevented after the fistula has formed. The appearance of pus in the fistulous opening, or the invasion of cholesteatoma into the interior of the semicircular canal, with a simultaneous deafness, renders the prognosis more unfavourable. The prog-

nosis is, furthermore, unfavourable in an established perforation of the promontory wall, which, with a simultaneous deafness, must be looked upon as a sure sign of a diffuse labyrinthine suppuration, and in which, as already mentioned, the destructive process not infrequently extends to the peripheral part of the internal meatus and to the auditory nerve. The extensive changes in this part of the labyrinth, already described (p. 551), illustrate the fact, confirmed by all observers, that the majority of cases of otitic meningitis ending fatally take their origin from the cochlea. According to Alexander (*Zeitschr. für Ohren-heilk.*, 1908), the meningitis produced by suppurations of the labyrinth runs a more favourable course than the otitic meningitis brought about by other causes.

Treatment.—The difficulty of the diagnosis, the full knowledge of the absolute loss of hearing which is still at hand, after an operative measure on the labyrinth, and the meningitis which not infrequently arises after such an operation, are the reasons why opinions differ so greatly as to the therapeutic measures to be used in suppurations of the labyrinth.

From the fact that the active labyrinthine symptoms arising during the course of an acute otitis are not always caused by suppurative infection of the labyrinth, but may be brought about by other changes which are capable of subsiding with more or less restoration of the hearing, are the reasons why an operative interference on the labyrinth in an acute otitis is out of the question, and only the free opening up of the antrum to relieve the pressure on the labyrinth is in place. Only in cases in which a labyrinthine suppuration has been positively diagnosed, and in which marked initial symptoms of a meningeal affection are present, and lumbar puncture gives a positive result, is one justified to proceed to the operative opening of the suppurative process in the labyrinth.

The indications for the operative treatment of chronic labyrinthine suppurations are as yet very vague. Many clinical and anatomical observations are still necessary to enable us to establish more exact indications for an operative procedure. While some advocate a conservative treatment when there are not urgent indications for the opening up of the middle spaces, and point to the fact that a post-operative meningitis often arises after the radical operation in cases in which a labyrinthine suppuration has been diagnosed (Heine, Manasse, Friedrich), others call attention to the cerebral complications which are brought about by labyrinthine suppurations, and which can be prevented in many cases by opening up the purulent, diseased labyrinth. This radical point of view is justly assumed by Kümmel, Hinsberg (*loc. cit.*), and others. The author also considers the opening up or eradication of the diffusely diseased labyrinth a measure to be employed only as a last resort, as it

is usually associated with a certain amount of danger in causing the infection to spread, giving rise to a fatal meningitis or some cerebral complication.

When establishing the indications for an operative procedure on the labyrinth, one must consider the following : (1) The symptom-complex causing the labyrinthine suppuration; (2) the degree of loss of hearing and the amount of disturbance in equilibrium and co-ordination; (3) the existence of cerebral complications; and (4) the conditions found at the labyrinth during the radical mastoid operation.

1. Labyrinthine symptoms, in which there is still some hearing power for speech, and in which the power of stimulating the vestibular apparatus is still preserved, contra-indicate the opening up of the labyrinth, even if a fistula is found in the semicircular canal, as in such cases there is a possibility of a post-operative meningitis.

2. Labyrinthine symptoms, with complete deafness and non-irritability of the labyrinth, indicate, especially with cholesteatoma and tuberculosis, the opening up of the labyrinth, regardless of whether a defect in the bony labyrinthine capsule is or is not found at the time of the operation. These are the cases in which a continuance of the labyrinthine suppuration may lead to a meningitis, and in which the radical operation is the only hope of preventing this occurrence. In addition, it must also be remembered that the continuance of the labyrinthine suppuration prevents the epidermization of the wound cavity after the radical operation. Considering the fear of a meningitis which may be brought about by the labyrinthine suppuration, one must not mind the loss of the slight hearing power which is still at hand as a result of the operation, because, as the observations of Alexander and Freytag show, the hearing distance, which is still found to be present to a certain degree, not infrequently gradually disappears entirely after a healed radical operation.

3. Caries of the labyrinth, which has been established before the operation, and which is associated with facial paralysis, indicates the opening up of the labyrinth.

4. Symptoms of a meningeal irritation arising after the radical operation indicate the immediate opening up of the labyrinth.

5. Symptoms of a cerebral complication create an urgent vital indication for opening up the labyrinth (Jansen).

The surgical procedure of opening up the labyrinth is governed by the local conditions found at the labyrinth at the time of the radical mastoid operation, and by the symptom-complex which existed prior to the operation —that is, whether symptoms of a cerebral complication are present or not.

If one finds, with a still considerable degree of hearing power and irritability of the labyrinth, a fistula in the semicircular canal at the time of the radical mastoid operation, one should not venture to curette this, because by

doing so the protective wall existing in the semicircular canal is destroyed, and the circumscribed labyrinthitis becomes a diffuse one. An exception to this is found in those cases in which cholesteatoma grows into the semicircular canal, whereupon the canal must be opened up and cleaned out until the liquor flows off. Voss (*Deutscher Otologentag*, 1906) reports a case of chronic middle-ear suppuration with cerebral symptoms, in which recovery took place after opening up the labyrinth, and after a profuse discharge of cerebro-spinal fluid from the semicircular canal and vestibule.

If, in addition to a fistula in the semicircular canal, the fenestra vestibuli is also open, or a fistulous perforation is found on the promontory wall by carefully probing, and there are no dangerous symptoms prior to the radical operation, it is best to remove the promontory wall piecemeal with the smallest sharp spoon, pressing from within out, thereby establishing an opening in the labyrinth, which drains well towards the tympanic cavity, and makes it possible for the parts to heal by the formation of granulations and connective tissue. Curetting the labyrinthine cavity seems, however, a serious step to the author, for the reason that in case there is already a perforation between the cochlea and the internal meatus, which presents no symptoms, the extension of the suppuration from the peripheral part of the acoustic nerve along the fibres of its central part towards the cranial cavity may be brought about. Only when careful probing of the labyrinthine cavity reveals the sequestrated modiolus should it be removed.

While probing, as well as during the operation in which the labyrinth is opened on its medial side, one must be careful not to injure the facial nerve.

Bourguet (cited by Hinsberg) states in his praiseworthy paper* that the distance between the horizontal part of the facial canal and the fenestra vestibuli is 3 mm., while the lateral part of the horizontal semicircular canal, which sometimes lies above and sometimes behind the facial canal, shows a variation in distance from 1 to 3 mm.   The distance between the cochlea and the carotid canal varies from 1 to 4 mm.   In order to protect the facial nerve, Bourguet devised a protector (*protecteur facial*), which is recommended by Hinsberg as being very serviceable.   The author is decidedly opposed to the use of burrs in the operation on the labyrinth (Jansen, Hinsberg), as they are never as safe as when operating with the chisel.

All operations on the labyrinth must be preceded by a thorough cleaning out of all the diseased tissue in the mastoid process and middle-ear spaces; in other words, we must first perform a complete radical mastoid operation.   The method to be employed in opening the labyrinth depends on the conditions found at the time of the mastoid operation.   Those most universally used are the Jansen, Hinsberg, Neumann, and Richards methods, depending on whether the labyrinth cavity should be opened from the lateral or medial side.

Jansen's Operation.—In this procedure the posterior part of the horizontal semicircular canal is chiselled away, and the vestibule is opened up by removing the bone backwards and upwards, care being taken not to injure the facial nerve.   Having removed this portion of the semicircular canal, the vestibule is opened anteriorly on the inner side of the ampulla or posteriorly by following the canal and taking away the bone towards the small end, thus entering the vestibule from behind and enlarging

* *Anatomie chirurgicale du Labyrinthe.*   Thèse de Toulouse, 1905.

the opening carefully in all directions, thereby making a free drainage for the labyrinthine cavity.

Neumann's Operation.—This method, which is based on the conditions found at the peripheral end of the acoustic nerve, is much more radical than the other labyrinthine operations. He approaches the labyrinth, or rather vestibule, from the posterior surface of the petrous bone. The posterior part of the pyramid is taken away until the openings cut on transverse section of the posterior and horizontal semicircular canals are visible, where-upon one advances to the internal meatus, lays open the peripheral end of the acoustic nerve, and finally removes the promontory. This method has the advantage over the other methods in that the facial nerve is less liable to be injured.

Hinsberg's Operation.—In this operation the labyrinth is entered by way of the fenestra vestibuli (oval window). If the stapes is still present, it is first removed, and a probe is then introduced into the oval window, under guidance of which the lateral portion of the horizontal semicircular ˜canal and vestibule are freely opened up.

Richards's Operation.—The main factor in this procedure is to expose the orifices of the three semicircular separately. This brings to view the so-called solid angle formed by the planes of the three semicircular canals standing at right angles to each other. At the place where the two vertical canals enter the vestibule is the point at which Richards endeavours to enter the labyrinth, and from here enlarges the opening until a free exposure of the vestibule is established. He also removes the bone between the oval and round windows and first turn of the cochlea by taking away the bone from behind anteriorly and inferiorly.

All these methods have their advantages and drawbacks, and must be selected in each case depending on the conditions found at the time of operation. In every case it is our main object to open up and clean out the labyrinth as thoroughly as possible, and to avoid injuring the facial nerve. The labyrinth operation must, however, be looked upon with a certain amount of dread, as extension of the suppurative process may easily be brought about by these manipulations, causing a serious cerebral complication or a fatal meningitis. It is, therefore, always advisable to consider well and resort to every conservative means before undertaking an operative procedure on the internal ear. In the great majority of cases the suppurative process becomes localized and drains off, so that surgical intervention becomes unnecessary and the threatening labyrinthine symptoms gradually subside, leaving, perhaps, a more or less permanent disturbance in the hearing.

The procedure after the operation and the after-treatment are but slightly different from those of the radical mastoid operation

(see p. 543). Loose tamponing and keeping the wound clean are the main objects. If all the diseased tissue has been removed, the loss of substance sustained by the operation fills up rapidly with granulations, and becomes covered with epidermis. Small sequestra, which·are even expelled during the treatment of the wound, do not act as an obstacle to a lasting cure. That deafness remains in the operated ear after the labyrinthine operation goes without saying.

Intracranial Complications.

(Special Part.)

The intracranial complications of otitic origin may be divided into the following groups:

1. Inflammations of the Meninges.

(*a*) Pachymeningitis   externa   circumscripta   (Extradural abscess).
(*b*) Pachymeningitis   interna   circumscripta   (Intradural abscess).
(*c*) Leptomeningitis diffusa and meningitis serosa.

2. Diseases of the Brain.

(*a*) Brain abscess.
    (1) Abscess of the temporal lobe.
    (2) Abscess of the cerebellum.
    (3) Metastatic abscesses.
(*b*) Ulceration of the brain and encephalitis diffusa.

3. Diseases of the Sinuses of the Dura Mater and of the Internal Carotid Artery.

(*a*) Thrombophlebitis of the sigmoid sinus, and of the bulb of the internal jugular vein.
(*b*) Thrombophlebitis of the superior and inferior petrosal sinuses and of the cavernous sinus.
(*c*) Erosion of the internal carotid artery and of the sigmoid sinus.

The Extradural Abscess and Pachymeningitis Circumscripta Externa.

Syn. : Epitympanic, perisinous, or epidural abscess ; periostitis interna cranii.

Extradural or perisinous abscess is brought about by the dura mater of the middle cranial fossa—or that part covering the posterior wall of the pyramid—being lifted away from its osseous attachment by a collection of pus between it and the temporal

bone. It is more often localized in the posterior than in the middle cranial fossa.

An extradural abscess occurs more frequently in acute than in chronic middle-ear suppurations. In the chronic middle-ear suppurations it is mainly the acute exacerbations, and especially the cholesteatomata, that bring about the formation of an extradural abscess.

A rare form of extradural abscess, which is described by Jansen, is the deep form originating from the labyrinth, and lying on the posterior surface of the petrous bone; such an abscess often arises from the labyrinth and the aquæductus vestibuli, causing an empyæmia of the saccus endolymphaticus, the bursting of which leads to the formation of an extradural abscess (Kummel, Schultze).

An epitympanic abscess arises, in the majority of cases, from the direct extension of the pus from the bone, which is infiltrated with purulent secretion or perforated by fistulæ, to the dura mater. Nevertheless, the osseous wall bordering on the abscess is often found apparently intact. In such cases the suppuration extends to the dura mater, in that the infectious material, which infiltrates the spaces in the bone, makes its way to the endocranium, or suters through the lymph and bloodvessels, in which case, no doubt, the virulence of the micro-organism plays an important part (pneumococci, Leutert).

The collection of pus between the temporal bone and dura is either encapsulated, or communicates with the middle-ear spaces through a perforation in the temporal bone. This latter condition is less dangerous than the former.

The extent of an extradural abscess depends not so much on whether the dura is more or less firmly united to the base of the skull, but mainly on its duration. When there are fistulæ in the bone at the tegmen tympani, which allow a portion of the abscess contents to flow off, the extent of the epidural abscess is smaller than when the tegmen tympani is intact. In the latter case the pus, which is under high pressure, may spread in different directions at the base of the skull.

Symptoms.—The symptoms of extradural abscess are seldom of such a characteristic nature as to present certain fixed signs which allow us to make a precise diagnosis (Hölscher). According to Hoffman (*Deutsche Zeitschrift für Chirurgie*, 1888), a diagnosis of extradural abscess may be made if, in spite of the complete opening up of the mastoid process, a group of threatening symptoms (meningeal irritation, fever, and intense pain localized over the entire temporal bone, with or without evidence of brain pressure) continues, or if symptoms of meningitis or of sinus phlebitis supervene. On the other hand, it may be said that the symptoms mentioned above also occur in general leptomeningitis and in brain abscess, and that, by the formation of solid and thickened masses of exudate on the external

surface of the dura mater, symptoms of brain pressure may be brought about. Somnolence, dizziness, vomiting, optic neuritis (Tenzer, *Archiv f. Ohrenheilk.*, vol. lv.), and nystagmus may also occur with an extradural abscess, yet they offer no positive data for making a differential diagnosis. When the extradural abscess has its seat in the posterior cranial fossa (deep extradural abscess), its presence is sometimes made evident by some local symptom such as torticollis (Jansen, Lane, Page), or if seated in the middle cranial fossa, by crossed pareses of the motor and sensory cerebral nerves. Impediments in speech when extradural abscesses were situated on the left side were observed by U. Pritchard, Macewen, and Salzer. Grunert reports the presence of sugar in the urine.

Diagnosis.—The diagnosis of sacculated extradural abscesses is very difficult; it is easier when the abscesses are diffuse. According to the author's observations, an important diagnostic symptom of extradural abscess is the rapidly alternating appearance and disappearance of threatening symptoms, especially the cessation of the symptoms of meningeal irritation after a sudden discharge of a large quantity of pus from the ear. According to Toti, an otorrhœa, the intensity of which is out of proportion to the size of the middle ear, and which is associated with symptoms of meningeal irritation, allows us to suspect an extradural abscess. According to Krause, unilateral headache, with absence of pain on pressure and percussion, is of value in making a diagnosis, if other cerebral complications can be excluded.

The diagnosis is aided if, during rarefaction òf the air in the external auditory canal by means of the pneumatic speculum, a drop of pus appears at the roof of the tympanic cavity, and by continuous rarefaction a great quantity of pus follows.

Prognosis.—The extradural abscess, if left to itself, leads to death, inasmuch as the dura mater becomes perforated by fistulæ in one or more places, and the pus, emptying into the base of the skull, leads to a leptomeningitis which runs a rapid course. The latter is also observed without perforation of the dura as a sequel of an extradural abscess. In other cases, before perforation of the dura mater takes place, an adhesion often forms between the dura and pia mater in consequence of a chronic inflammation on the inner surface of the former. In such cases, when a fistulous perforation does occur, the spread of the suppuration to the base of the skull is prevented; but owing to the extension of the pus to the brain, however, a cerebral abscess is formed, and in rare cases an ulceration of the brain. A sinus phlebitis occasionally develops owing to the extension of the abscess to the sigmoid sinus. Spontaneous cure of an extradural abscess may result if, after exfoliation or extraction of a sequestrum of the tegmen tympani and antri, the abscess empties

itself completely externally, and if the inflammation has not as yet extended to the inner surface of the dura mater. Baumstein (*Archiv für Ohrenheilk.*, vol. lv.) reports rupture of the abscess through the suture between temporal and occipital bones; Chavasse (*Archiv int. de laryng.*, 1904) reports rupture through a fistula in the squamous bone.

Treatment.—The only treatment of extradural abscess is the free exposure of the dura mater and incision of the abscess cavity to create free drainage. In acute cases the operation is performed after laying bare the antrum; in chronic middle-ear suppurations, after the radical mastoid operation. The operation is indicated in all cases of acute or chronic middle-ear suppuration in which there are symptoms of an intracranial complication which come on after the opening up of the mastoid process or the middle-ear spaces. In such cases the dura mater is exposed freely, even if the diagnosis of an extradural abscess is not positive, in order to eventually explore for an intradural or brain abscess. If a fistulous opening is found in the tegmen at the time of operation, it must be cautiously widened with the chisel and hammer and traced to where the dura is found to be discoloured or covered with granulations. The dura can be raised without danger from the edges of the bony aperture, in order to thoroughly examine its condition. If the tegmen is not perforated, a part is removed with a narrow chisel and the opening carefully widened. When the abscess cavity has been found, the pus, according to Manasse, is thick, yellow, and opaque, while in diffuse meningitis it is more serous or only cloudy.

After the extradural abscess has been evacuated, the exposed dura mater is examined for fistulous openings, deposits, or granulations. If, after opening up an extradural abscess, a fistulous opening is found in the dura mater, or if it appears markedly tense and presents no pulsation, exploration of the temporal lobe, and eventually also of the sigmoid sinus if the temperature is high, may become necessary. Thickened, ill-coloured deposits and fungoid granulations of the dura mater are carefully removed. According to Heine, splinters of bone arising from the operation, and impacted between the tegmen and dura, should be carefully removed, as they can produce a pressure necrosis of the dura which may give rise to a fatal meningitis. The after-treatment of the wound following the operative opening of the extradural abscess is identical with that described in the radical operation (p. 543).

The author cannot agree with the suggestions of Lane and Körner to expose the dura mater of the middle and posterior cranial fossæ in those purulent and cholesteatomatous affections of the temporal bone which run their course without intracranial complications, as the author has seen at his clinic annoying headache arise, after exposure of larger portions of the dura, owing to the formation of adhesions between the dura and the edges

of the bony opening, in spite of the fact that the wound ran a normal course.

The inflammation which is observed with large perforations of the tegmen tympani, and is confined to the outer surface of the dura, and which is termed pachymeningitis externa, differs from an extradural abscess. It may exist for a long time without giving rise to any symptoms. One therefore sometimes finds, at the radical operation, quite extensive areas of the dura of the middle cranial fossa lying freely exposed and covered with thick layers of exudate or granulations, without any previous symptoms of a meningeal irritation.

Pachymeningitis Interna Circumscripta.

Syn. : Abscessus intraduralis, subduralis, intrameningealis.—
Leptomeningitis circumscripta.

A circumscribed collection of pus internal to the dura mater, between it and the pia mater, usually occurs when there is a fistulous perforation of the dura, and when an adhesion has formed between the dura and pia mater in the neighbourhood of the ulceration. Such a collection of pus either leads to ulceration and softening of the surrounding parts of the brain, to a brain abscess, or to a diffuse leptomeningitis. Cases of cure after the operative opening of intradural abscesses have been frequently observed. As the group of symptoms of circumscribed pachy-meningitis differs but slightly from that of leptomeningitis (Jansen), and in case the diagnosis of the latter is not made certain by spinal puncture, it is imperative that the dura is exposed and incised as soon as possible, as it is only by this means that, in some cases, a diffuse leptomeningitis can be prevented.*

Leptomeningitis Diffusa Purulenta of Otitic Origin, and Meningitis Serosa.

Leptomeningitis diffusa purulenta is brought about by the extension of purulent processes in the temporal bone, through perforation in the tegmen tympani and antri, more rarely in the posterior surface of the pyramid, but most frequently, however, through extension of a labyrinthine suppuration by way of the internal meatus to the base of the skull. Sometimes the suppuration forces its way from the carotid canal (Meier), or along the facial nerve into the internal auditory canal, and from here to the interior of the skull (Macewen, Politzer). In cases of sinus thrombosis, also, the thrombus which has become infected may likewise bring about a metastatic leptomeningitis through contact of the pia mater with the medial sinus wall (Manasse). Not infrequently,

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* Barr, *VII. Intern. Otologenkongress*, Bordeaux, 1904; P. Chavasse, *VII. Intern. Otologenkongress*, Bordeaux, 1904; Frémont, *Soc. franç. d'otologie*, 1905; Heine, *Festschr. f. Lucae*, 1905; Riär, *Verh. d. dän. Otolaryng. Ver.*, *Monat. für Ohrenheilk.*, 1905; Mendes, *Arch. ital. di otol.*, 1905.

especially in the acute otitis of influenza, one cannot find ana-tomically a direct connection between the meningitis and the suppuration in the ear, and it is probable in these cases that the spread of the inflammation from the middle ear to the cranial cavity is brought about by the lymph-sheaths of the anastomotic bloodvessels. According to Wittmaak (*Zeitsch. f. Ohrenheilk.*, vol. xlvii.), extension of the bacteria can take place from the cavum hypotympanicum through small vessels and the sheaths of the glosso-pharyngeal, vagus, and accessory nerves.

Meningitis of otitic origin develops either after the formation of a fistula in the dura mater or without this, *ex contiguo*, from the inflamed external surface of the dura mater. Extensive carious defects in the tegmen tympani and antri, which are not infrequently found when performing the radical operation, do not seem to favour the development of leptomeningitis. That the dura, which has become exposed through destruction of the tegmen tympani, withstands the invasion of the pus is shown by specimens in the author's collection, in which the outer surface of the dura directed towards the osseous defect is covered with firmly adhering masses of exudate, while the inner surface directed towards the pia mater shows no changes at all.

When the dura is perforated by a fistula, the parts surrounding the place of rupture appear infiltrated, thickened by deposits of exudate, undermined with pus, and detached from the bone. The size of the fistula in the dura varies from that of a pin's head to $1\frac{1}{2}$ cm. and over. Sometimes the dura mater is per-forated at several places corresponding to the sieve-like perfora-tion of the tegmen. The purulent infiltration of the pia mater is at times—especially in circumscribed adhesions with the dura—limited to only one part of the base of the brain; not infrequently, however, it extends unequally from the base of the brain to the convexity of the cerebral hemispheres, and as far as the cauda equina. The purulent infiltration is most marked along the lymph-sheaths of the large vessels. The cortex of the brain beneath the purulent and infiltrated pia mater is softened, the cerebro-spinal fluid cloudy and flaky; the widened ventricles filled with sero-purulent fluid, and the bloodvessels of the pia sometimes thrombosed. In meningitis of the posterior cranial fossa induced by suppuration of the labyrinth, the inflammation at times extends to the vertebral canal, with symptoms of spinal meningitis.

Symptoms.—The clinical picture of leptomeningitis diffusa purulenta of otitic origin is not always the same. The illness usually begins with headaches, which are at first of a remitting character. In the further course of the affection they spread over the entire head, become more severe with motions of the body, and finally become continuous.

In addition to these headaches, there are generally persistent

vomiting of gall or mucus, sleeplessness, sensitiveness against light and noise, somnolence, and hyperæsthesia of the cutaneous nerves. Lightly tapping the muscles calls forth an active reflex. Upon striking the spinal column, an inward curvature is brought about (Oppenheim's back phenomenon). Characteristic for this affection, which differentiates it from all other otitic intracranial complications, and especially from brain abscess, is the marked excitement which is made evident in screaming, springing from the bed, endeavours to run away, plaiting the bed-clothes, picking at the bed-clothes, etc. With the extension of the inflammation during the further course of the disease—especially in extensive basal and cerebral meningitis, less often in circumscribed meningitis of the posterior cranial fossa—consciousness always becomes more cloudy. Delirium and symptoms of cerebral irritation develop, and one notices contractions of the muscles of the extremities and face, especially on the affected side; these increase to general convulsions, and are mostly associated with rigidity of the muscles of the neck. Severe pains in the back allow one to assume with probability that the inflammation has extended to the meninges of the spinal cord. Paralyses of the abducens and facial nerves occur in rare cases. The pupils are generally markedly contracted and react slightly to light; the muscles of the abdomen are usually drawn in. Optic neuritis is frequently met with, but is not constant; choked disc is less often observed than in brain abscess. In addition, there is generally an alternating nystagmus, which is sometimes directed to the one and sometimes to the other side. The fever shows great variation; sometimes it is low, showing a moderate fluctuation ranging from 99° to 101° to 102° F., and then again it is very high, especially with a cortical meningitis, ranging to 104° to 105° F.; sometimes it is ushered in with rigors, and at times there is a glycosuria. The pulse is almost always accelerated in the beginning of the disease, is often arrhythmic, becomes slower in the further course of the affection with the increase of the cranial pressure, and again becomes more rapid in the last stages of the illness. At times albuminuria is observed in cases running an acute course. Finally, paralyses develop, such as a paralysis of one of the extremities, or there may be a hemiplegia, a paralysis of the muscles of the eye, of the bladder, and of the rectum, as well as a rigidity of the muscles of the neck; the pupils become dilated, there is a loss of speech (Voss), the respiration becomes accelerated, the pulse small and frequent, and death ensues with symptoms of general paralysis, the patient being in a state of coma.

In reference to the seat of the meningitis. it must be mentioned that when the affection is confined to the base of the cerebrum, paralyses of the muscles of the eyes and face are observed; when there is an exudation into the fossa of Sylvius, impediments in

speech are evident (Takabatake, *Zeitschr. für Ohrenheilk.*, vol. xlvi.); and that when the spinal meninges are simultaneously affected, spinal cord symptoms arise. In meningitis of the posterior cranial fossa, consciousness is retained a long time. Of the accompanying symptoms, the abducens paralysis and the rigidity of the muscles of the neck are especially pronounced. Death ensues rapidly owing to the arrested respiration. In a meningitis of the cortex, consciousness disappears early and the agonale condition lasts much longer. Sometimes a paralysis of the extremities on the side of the body corresponding to the affected ear takes place, and is due to the extension of the meningitis to the opposite cranial hemisphere. The inability to extend the knee-joint when bending the leg (Kernig's flexion contraction), as observed by Jansen and confirmed by Körner, has been repeatedly observed by the author. This symptom also occurs, moreover, in all affections associated with rigidity of the spinal column.

Of the group of symptoms mentioned above, several marked phenomena, such as convulsions, contraction and dilatation of the pupils, etc., may be entirely wanting. In a number of cases of general meningitis of otitic origin observed in the author's clinic, no striking symptoms could be noted beyond headaches, somnolence, and, finally, coma.

Course.—The course of otitic meningitis is sometimes slow and sometimes rapid. The meningitis which occurs in acute, as well as in chronic middle-ear suppurations of children takes a rapid course, and ends in death within two to three days. The author has seen a case of meningitis take a very rapid and severe course (within a few hours) after the rupture of an extradural or brain abscess into the base of the skull. In the protracted forms, which arise mostly from ulcerations of the dura mater or from an extradural abscess, intermittent headaches, contractions of the muscles of the face, or facial paralysis, often precede for months the occurrence of the violent symptoms. Even after the appearance of manifest and pronounced meningeal symptoms, the vomiting, unconsciousness, and convulsions may entirely cease, and the condition becomes apparently normal for a longer or shorter period. Such attacks, which appear in paroxysms, in which. moments of remission alternate with complete loss of consciousness, often recur several times at greater intervals, until finally, 'after weeks or months, the illness ends in death, either with very severe symptoms, or with the patient in a comatose condition and a general paralysis.

Terminations.—Otitic meningitis runs, with but few exceptions, a fatal course. In circumscribed meningitis, which develops *ex contiguo* in consequence of an extradural abscess, the possibility of a cure is not out of the question if the abscess dis-

charges spontaneously into the middle ear or has been evacuated by operative measures. That a cure may also be obtained at times in purulent leptomeningitis by opening up the middle-ear spaces has been proved by the cases observed by Gradenigo, Macewen, Barr, and Brieger,* in which the diagnosis of diffuse leptomeningitis was made certain by the positive result of the lumbar puncture. On the other hand, a great number of cases which run their course with optic neuritis, and which are reported as cured cases of purulent leptomeningitis, should come under the category of meningitis serosa.

Diagnosis.—The diagnosis of leptomeningitis diffusa purulenta of otitic origin can seldom be positively made, on account of the erratic clinical symptoms of the affection, and because an extradural abscess, circumscribed leptomeningitis, and a brain abscess, may also run their course with the same group of symptoms. In children, more rarely in adults, typical meningeal symptoms may develop merely by the retention of pus in the middle ear, which rapidly disappear after the tension has been relieved by paracentesis. Only in cases in which the affection runs its course with the typical group of symptoms already mentioned may the diagnosis of meningitis be made with probability. The author would like to lay special stress on the spinal symptoms observed in leptomeningitis, as they are of importance in the differential diagnosis between this affection and brain abscess. Of these spinal symptoms, attention must be called to the following: the increase of the tendon reflexes, Westphal's symptom, paræsthesia and hyperæsthesia in the extremities, paralyses of the bladder and rectum in patients who are not comatose, paraplegia, and tonic spasms of the muscles of the back and extremities.

By means of the lumbar puncture suggested by Quincke in 1891, we are in a position to measure the pressure of the cerebro-spinal fluid, and to conclude, by microscopic examination of the fluid as well as by its power of coagulation, whether there are inflammatory changes in the cerebro-spinal space. When the result is positive, microscopic examination of the fluid shows the presence of pus cells and pus-producing micro-organisms (strep-tococci, Lichtheim)—staphylococci, diplococci, tubercle bacilli, and the *Bacillus pyocyaneus* (Voss)—the virulence of which may be tested by inoculation into animals. According to the experience of the author, only a positive result of lumbar puncture is absolutely conclusive, while a negative result does not exclude the presence of purulent meningitis.

Prognosis.—The prognosis of leptomeningitis diffusa purulenta of otitic origin is, as a rule, unfavourable. Nevertheless, one must be guarded in giving a prognosis at the beginning of

* *Transactions of the Sixth Otological Congress in London*, 1899, by Dr. Cresswell-Baber, London, 1900.

the disease, inasmuch as marked meningeal symptoms may be caused even by hyperæmia of the meninges (in children), as well as by extradural abscesses and meningitis serosa. Only when the symptoms of meningitis become more prominent may a fatal termination be predicted with great probability. In spite of the fact that the prognosis is, as a rule, unfavourable, cases of meningitis are now more frequently reported which have been cured by operation, and in which leucocytes and bacteria have been found in the lumbar puncture fluid.

In the last few years various operative methods have been devised in otitic meningitis to establish a free outflow to the pus by incision of the dura and drainage (Hinsberg, Lermoyez, Voss, Brieger, Barth). Although these measures have been accompanied thus far by little success, still, a great deal is to be hoped for in the future.

Meningitis serosa is an intracranial affection of otitic origin which was first described by Quincke. The anatomical characteristic features of this disease are a serous infiltration of the pia mater, and an increase in the cerebro-spinal fluid in the subarachnoid space and in the ventricles of the brain. The surrounding brain tissue is infiltrated with serous exudate. According to Hammerschlag,* the sigmoid sinus can be completely compressed owing to a large collection of fluid in the ventricles. Meningitis serosa occurs less often in acute than in chronic middle-ear suppurations, and is the result of an inflammatory irritation of the meninges, which has taken its origin from the pus in the temporal bone; according to Jansen,† it is caused most frequently by a labyrinthine suppuration.

Serous infiltration of the meninges and an increased amount of cerebro-spinal fluid are often found with extradural or brain abscess and sinus thrombosis. Sometimes, however, when there is an abscess lying outside the dura mater, a group of symptoms arises, the favourable course of which leads us to believe that the case is one of an abating meningitis serosa.

Symptoms.—The symptoms of serous meningitis differ but slightly from those of the purulent form. The symptoms are: headaches which spread over the entire head, sensitiveness on percussion, dizziness, restlessness, vomiting, torticollis, hyperæsthesia, ataxia, pareses, strabismus, disturbances of vision and hearing, delirium, and somnolence. The fever seldom reaches a high degree, and may even be entirely wanting. That the vertebral canal has become involved in the inflammatory process is made manifest by rigidity of the spinal column and by pain in the knees.

Course.—If the anatomical conditions which produce serous meningitis continue, death ensues. The meningitis can, however,

* *Wiener med. Wochenschr.*, 1900.
† *Comptes rendus du XII. Congr. intern. de méd.* at Moscow, 1897.

rapidly subside if the seat of infection is removed by an early operative interference. The disappearance of the meningeal symptoms after the laying bare of the seat of infection (as the author has repeatedly observed in his clinic) cannot, however, be regarded as a characteristic feature of serous meningitis. The reason for this, as has already been pointed out, is that in the purulent form, in which the lumbar puncture has proved the existence of pus in the cerebro-spinal fluid, a cure has also been observed after operative procedures. As a rule, however, the prognosis is more favourable in cases in which the cerebro-spinal fluid is clear and free from bacteria.

Diagnosis.—The diagnosis of serous meningitis may therefore be made with great probability only if the symptoms of meningitis and brain pressure disappear spontaneously or shortly after an operative interference. During the time that severe brain symptoms are in evidence, serous meningitis cannot be distinguished from the purulent form, from extradural abscess, and even from brain abscess. According to Jansen (*loc. cit.*), the diagnosis of serous meningitis is confirmed by the presence of a fistula in the semicircular canals and by optic neuritis.

Lumbar puncture is not an absolutely reliable guide in making a diagnosis, because, in the purulent form of meningitis, a cerebro-spinal fluid free from pus and germs is also found. In addition to this, it must be remembered that not infrequently a serous exudation in the meninges is a forerunner of purulent meningitis.

The quantity and quality of the fluid obtained by lumbar puncture, as well as the increased pressure in the cerebro-spinal space, are of diagnostic value to a certain measure, inasmuch as similar changes are found in all intracranial complications.

Lumbar puncture is performed with the patient lying on the side and the knees drawn up so that they almost touch the abdomen, causing a bending of the back. It is usually carried out without a general anæsthesia, but in all cases it is advisable to inject a few drops of a 3 to 5 per cent. solution of cocaine into the skin at the place where we wish to introduce the puncture needle. Having done this, and the part having been sterilized with alcohol and tincture of iodine, a sterile straight needle, about 5 to 6 inches in length, is introduced between the third and fourth lumbar vertebræ. The needle, which has a diameter of about 0·6 to 1·2 mm. and a length of 12 cm., is passed into the lumbar part of the subarachnoid space laterally to the spinous processes. This is quite easily accomplished, as the intervertebral foramina, closed in by ligaments, become widely separated when the vertebral column is bent forwards. In children, the needle is inserted between two spinous processes, and in a direction slightly upwards; in adults $\frac{1}{2}$ to 1 cm. laterally to the median line of the body, and the point of the needle directed towards this

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line. The point of the needle enters the subarachnoid space at a depth of 2 to 6 or 8 cm., depending on the thickness of the fat and muscles. That the puncture has been successfully performed is made evident by the escape of spinal fluid through the needle. The pressure in the cerebro-spinal space can be judged by the rapidity with which the fluid flows from the needle—that is, whether it escapes in drops or in a continuous stream. The withdrawal of too large a quantity of fluid may produce collapse; 8 to 10 grammes are sufficient for a thorough examination.

The puncture fluid is clear or cloudy. The latter is found with purulent meningitis, with superficial brain abscesses (Alexander, *Monat. f. Ohrenheilk.*, 1904), and with accumulations of pus in the ventricles. The absence of the coagulation of fibrin in a clear puncture fluid also points towards a meningitis (Alexander).* The finding of tubercle bacilli, streptococci, or diplococci in the fluid allows one to conclude with great probability that the case is one of purulent or tubercular meningitis. The examination for anaerobic micro-organisms (Ghon) is of diagnostic importance. Leucocytes alone are not, according to Siebenmann, proof of a meningitis. The finding of streptococci† and tubercle bacilli in the fluid makes the prognosis unfavourable.

In examining the cerebro-spinal fluid obtained by spinal or lumbar puncture one must consider (1) the pressure under which the fluid escapes; (2) the colour—that is, whether it is clear, cloudy, or hemorrhagic; (3) the bacteriological examination; (4) the cellular count; and (5) the chemical findings.

1. The pressure under which the fluid escapes under normal conditions shows a moderate pressure, varying from 10 to 20 minims per minute. This varies according to the pathological changes, so that one finds an increase in the pressure in severe inflammatory conditions, such as meningitis, tumours of the brain, and, in fact, in all intracranial lesions in which there is a marked increase in the cerebro-spinal fluid.

2. The colour is normally clear, but becomes more or less cloudy, depending on the severity of the intracranial or spinal infection. This discoloration depends on the amount of blood and micro-organisms; in cases in which these are scanty the colour shows only slight variation from the normal, while in cases in which they are abundant the colour may range from a slight cloudiness to an almost opaque milky fluid.

3. The bacteriological examination is very important, as it enables us to ascertain the form of meningitis with which we have to deal. Such tests are made by microscopic examinations, by cultures, and by inoculations into animals. The predominat-

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* *Deutsche med. Wochenschr.*, 1905.

† Gruening found streptococci in the puncture fluid of a case which was operated for brain tumour, and which recovered.

ing organisms are usually the streptococci, the *Diplococcus intra-cellularis*, the tubercle bacilli, and often a mixed infection. In the ordinary meningitis of otitic origin we usually find the streptococci and staphylococci. In the tubercular meningitis the tubercular bacillus is the predominating organism, although there is often an admixture of other bacteria. The more severe the bacterial invasion, the more severe will be the intracranial or spinal lesion.

4. *The Cellular Count.*—In computing the cell count in the spinal fluid, we take into consideration the numerical increase in the lymphocytes and polynuclear leucocytes. An increase in these elements is always associated with an increased meningeal irritation. A lymphocytosis is usually found with a meningeal disorder, with or without the presence of pus-producing micro-organisms. An increase in the polynuclear leucocytes is observed in the various forms of meningitis, and give rise to a more or less cloudy fluid.

5. *Chemical Examination.*—In making a chemical examination of the spinal fluid, we look for the amount of albumen and globulin, as an increase in these elements is found in tubercular, meningococcic, and purulent meningitis. The presence of glucose shows some variations in quantity. This is usually slightly reduced in poliomyelitis and meningismus, and shows quite a reduction in tubercular meningitis. It has been found that when there is a reduction in the cell count, albumen, and globulin, with an increase in the sugar, but without a simultaneous diminution in the number of pathogenic micro-organisms, the prognosis is generally unfavourable, and such cases, as a rule, end fatally.

According to present views, lumbar puncture is not a fixed or positive indication for an operative procedure, because, as Hammerschlag was the first to show, the mere finding of leucocytes and micro-organisms in the spinal fluid does not contra-indicate an operative measure into the cranial cavity. According to Alexander,* it is recommended, even when there is a slight indication of meningitis, to perform lumbar puncture first, in order to ascertain the condition of the meninges at the time of the operative procedure. From this it would then be seen that many a meningitis declared to be post-operative, and being only slightly evident clinically, had already existed before the operation. Cozzolino disregards lumbar puncture entirely in tubercular meningitis. The quantity of puncture fluid varies from a few drops to 20–30 c.c. If one has missed the lumbar sac, if there are adhesions in the spinal subarachnoid space, or if the communication between the basal and spinal subarachnoid spaces is interrupted, the tap may be dry and no fluid will escape. Violent headaches, transient disturbances of hearing, and weakness in

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* Chapter *Chirurgische Erkrankungen des Ohres* in Professor Hochenegg's text-book on *Chirurgie und Operationslehre.*

the lower extremities in consequence of injury to the cauda equina, have been observed after lumbar puncture. Subnormal temperatures should not give rise to anxiety if they are not accompanied by collapse (Bönninghaus). Voss (*Zeitschr. für Ohrenheilk.*, vol. liii.) saw aspiration of air through the cannula during a deep inspiration.[*]

Another condition to which the writer wishes to call attention is the so-called meningismus. In this condition we have an irritability of the membranes covering the brain, which is associated with all the symptoms of a true meningitis. The difference, however, lies in the fact that, with a true meningismus, the spinal fluid may or may not be cloudy, but is free from bacteria, and there are no pathological changes of a lasting or serious nature. Such an irritation of the meninges is usually of a transitory nature, and is generally found as a complication of a purulent otitis media, mastoiditis, or sinus thrombosis. The treatment is similar to a true meningitis in that the focal lesion must be cleared up, and by so doing the meningeal irritation becomes less until the meningeal symptoms gradually subside and the patient returns to his normal state. As in a true meningitis, it often becomes necessary to resort to lumbar puncture in order to relieve the intracranial tension, and in this way to arrest the meningeal irritation.

Treatment.—The main factors in the treatment of serous meningitis, when meningeal symptoms make their appearance, consist in the early opening up of the middle-ear spaces, exposing the dura mater in the region of the tegmen tympani and antri for the purpose of exploring for an accumulation of pus in the form of an extradural abscess, and, if found, to incise the dura and give free vent to the encapsulated pus. The diagnosis of serous meningitis can be made with certainty by the bacteriological examination of the spinal fluid, and if, in performing lumbar puncture, the cerebro-spinal fluid is discharged in large quantities and under high pressure, and if the meningeal symptoms rapidly subside. If the severe symptoms continue after cutting through the dura, exploration for a brain abscess is indicated, and eventually puncture of the ventricles is to be tried (Jansen, Bönninghaus, Lannois, Müller). Lumbar puncture seems to have no essential influence on the course of the disease, with the exception of alleviating the symptoms; still, in those cases in which a cure of the meningitis has been reported, a certain amount of importance must be attached to the repeated use of the lumbar puncture (Cohen, *Zeitschr. für Ohrenheilk.*, vol. xxxviii.).

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[*] Grossman, *Berliner otol. Ges.*, 1905; Grunert, *Münchener med. Wochenschr.*, 1905; Hölscher, *Med. Korrespondenzbl. d. Würtemberg. ärztl. Vereins*, 1905; Voss, *Charitéannalen*, vol. xxix.; Lombard et Caboche, *Congr. int. de Bordeaux*, 1904; A. Knapp, *Arch. of Otology*, vol. xxxiii., 1904.

Brain Abscesses of Otitic Origin.

A brain abscess develops either through continuity by the direct extension of the suppuration to the cerebral substance, or at some distance from the seat of infection in the temporal bone, without any demonstrable macroscopic connection. A careful examination of the latter condition, however, often shows a purulent infiltration of the apparently non-infected bone, and an inflammatory condition of the dura mater and parts of the brain bordering on the osseous tissue. The exposed dura mater appears thickened by the deposit of an exudate on its external surface, often adherent to the adjoining part of the brain, and sometimes perforated by one or more fistulæ.*

In cases in which every trace of disease of the bone is lacking, the spread of the inflammation to the brain may be caused either by a phlebitis and the formation of thrombi in the veins entering the cranial cavity from the ear (from the thrombosed vena auditoria, Jansen), or by the migration of bacteria along the interstices of the connective tissue bands which accompany the anastomotic blood- and lymph-vessels of the middle ear and cranial cavity. In such cases the dura lying over the abscess is unaltered, but may, however, be covered with granulations and pus. In rare cases the aquæductus vestibuli may·be looked upon as one of the paths by which the infection is transmitted to the cranial cavity (Boesch,† Politzer,‡ Wegener).§

According to Von Bergmann,‖ brain abscesses of otitic origin are generally located in the temporal lobe or in the hemisphere of the cerebellum on the same side as the infected ear; the latter is mostly caused by perforation of the posterior surface of the pyramid or by the intervention of a labyrinthine suppuration. In the majority of cases, the abscess lies in the neighbourhood of the aural infection (Körner).

In 100 cases observed by Körner, the seat of the abscess was in the temporal lobe sixty-three times, in the cerebellum in 31 per cent., and both of these parts of the brain were simultaneously affected in 6 per cent. According to Heimann's statistics, the proportion of abscesses in the temporal lobe to those in the

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* According to Körner's statistics, out of 100 cases quoted in literature the brain substance between the dura mater and the brain abscess was softened in 17 per cent., adherent to the meninges of the brain in 26 per cent., and perforated by fistulæ in 15 per cent.; in 42 per cent. a fistula was found which ran through the dura mater and cortex of the brain, and brought about a communication between the collection of pus in the temporal bone and the brain abscess.

† *Zeitschr. f. Ohrenheilk.*, vol. l.

‡ *Archiv f. Ohrenheilk.*, vol. lxv.; and Passow, *Verh. d. D. otol. Ges.*, 1906.

§ *Archiv f. Ohrenheilk.*, vol. lxviii.

‖ *Die chirurgische Behandlung der Hirnkrankheiten* (*Arch. f. klin. Chirugie*, vol. xxvi.).

cerebellum is 68·3 to 31·7 per cent.; according to Neumann, 63·4 to 36·6 per cent.*

The exceptional cases in which abscesses are found in the hemisphere of the brain opposite to the diseased ear can no doubt be looked upon as pyæmic metastases; in this way abscesses may also lodge in various other parts of the brain, and in other organs. Not infrequently a brain abscess is combined with purulent meningitis and phlebitis of the sinuses of the dura mater.†

As to the location of brain abscesses in relation to the seat of the pus in the temporal bone, the following is usually observed: abscesses in the cerebrum—that is, in the temporal lobe—develop from suppurations in the temporal bone which extend over to the middle cranial fossa, whereas abscesses in the cerebellum occur, as a rule, with labyrinthine suppurations, in purulent inflammations, or caries of the posterior surface of the pyramid, occasionally in suppurations of the mastoid process (Pomeroy), and with an infectious sinus thrombosis. Dupuy, Körner, and the author have observed cases in which abscesses were situated in parts of the brain which did not correspond to the collection of pus in the temporal bone. Abscesses in the pons, in the crura cerebelli, in the medulla oblongata, and in the occipital lobe are very rare.

The seat of the abscess in the temporal lobe is usually over the tegmen tympani and antri. Cerebellar abscesses are generally in the anterior and inferior parts of the hemispheres—in other words, in those parts which correspond to the carious perforation on the posterior surface of the pyramid. Cerebellar abscesses arising from the labyrinth or its surrounding parts generally lie in the median part of this organ; those arising from the sigmoid sinus and its neighbourhood, in the lateral section of the cerebellum. These relations are of importance, and must always be kept in mind when exploring for a brain abscess.

The number and size of brain abscesses vary greatly. As a rule, there is only one abscess; multiple abscesses communicating with each other, or collections of pus which are completely isolated, are by no means rare. In a number of cases, abscesses have been found in the cerebrum and cerebellum at the same time (by Heimann eleven times in 645 cases). At times there is a fistula between the dura mater and the brain abscess, through which, under favourable conditions, the contents of the abscess may discharge through the tympanic cavity into the external auditory canal. The size of the abscess varies from that of a

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* Neumann, *Der otitische Kleinhirnabszess,* Deutike, Leipzig. Vienna, 1907.
† Brieger, *Vers. deutsch. Naturf. u. Aerzte,* Wien, 1894; Schubert, *Vers. deutsch. Naturf. u. Aerzte,* Wien, 1894; Schmiegelow, *A. f. O.,* vol. xxvi.; De Rossi, Congress in Rome, 1895.

pea to that of a goose's egg and over. In several cases observed by the author, the cerebral abscess occupied almost the entire temporal and frontal lobes of the brain. Cerebellar abscesses, as a rule, attain only a small size. In a case observed by the author, in which the diagnosis of a cerebellar abscess was made, the entire cerebellum was transformed into a large pus cavity. Heimann (*Archiv f. Ohrenheilk.*, vol. lxvi.), who collected the cases scattered through the literature, found that, in 645 brain abscesses brought about by acute and chronic middle-ear suppuration, 457 were cerebral and 188 cerebellar.

Abscesses which have existed for some time are often enclosed by a connective-tissue capsule, which may reach a thickness of 5 mm. The time it takes for a capsule to develop in chronic otitic abscesses is difficult to state. According to Lebert, Schott, Huguenin, and Gull, it takes from three to twelve weeks. Jansen saw a fully-developed abscess capsule five weeks after the appearance of an otitis media acuta, and ten days after the first symptoms of the formation of an abscess. Uchermann (*Zeitschr. f. Ohrenheilk.*, vol. xlvi.) estimates the age of the abscess by the thickness of the capsule. According to Neumann's investigations* at the author's clinic, it is not the duration of the abscess alone, but the kind of bacteria, which is the determining factor. Diplococci favour the formation of a capsule; when there are anaerobic micro-organisms present, a firm capsule is not formed. This fact is of importance in the post-operative course of the wound. According to Preysing,† the encapsulation of the abscess takes place when the virulence of the bacteria is low, while if the virulence of the pathogenic bacteria is high, the organism finds no time to dam in the infectious material.

According to the cases of brain abscess collected by Hessler, thirty-two out of forty-nine which followed a chronic middle-ear suppuration were encapsulated; of thirteen which arose after an acute middle-ear suppuration, five were encapsulated.

Brain abscesses, as a rule, affect the surrounding tissue, even when the capsule is intact; this is made evident by softening of the adjoining parts of the brain, flattening of the convolutions, and infiltration of the cortex. In like manner there is not infrequently even before rupture of the abscess takes place, a hydrops of the ventricles, or a serous, sero-fibrinous, or purulent meningitis. An encephalitis occurring with a middle-ear suppuration without a brain abscess is very rarely met with (Oppenheim).‡

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* *Loc. cit.*, p. 637.   † *Archiv f. Ohrenheilk.*, vol. li

‡ Cp. Th. Barr, *Glasgow Med. Journal*, 1878; Orne Green, *Med. and Surg. Reports of the Boston City Hospital*, 1877, Second Series; Moure, *Revue hebdom. de laryng., d'otol.*, etc., No. 43; Okuneff, Internat. Med. Congress, Moskau, 1897; Gruening, *Transactions of the American Otolog. Soc.*, *Thirty-first Ann. Meeting*, 1898.

Symptoms.—The clinical course of otitic brain abscess may be divided into four stages: the initial, latent, active, and terminal.

In the first stage, the symptoms are hidden by the symptom-complex of the original suppuration. The symptoms of the second stage are so vague that the diagnosis cannot be made from them alone (fatigue, loss of weight, sleeplessness, pale colour, loss of appetite). The third, active stage usually shows marked symptoms of the brain abscess.

In this stage the following symptoms are of special importance:

1. **Symptoms of the suppuration** are: Paroxysms of fever, rigors, general exhaustion and weakness, a failing of the general state of the patient (mostly in cerebellar abscess), anorexia, disturbances of digestion, odour from the mouth, and a remarkable increase in the temperature in the region of the affected half of the skull, which has already been pointed out by Broca. The general temperature frequently shows no considerable increase; in fact, according to Oppenheim, if there is a considerable and persistent increase in the temperature, it is not improbable that the brain abscess is complicated with some other condition. Leutert and R. Hoffmann, who are also of this opinion, attribute the secondary development of a meningitis as the cause of the rise in temperature. Schmiegelow and Körner have observed a herpes labialis. Not infrequently, according to the observations of the author, there is a headache localized in the parietal region of the affected side when there is an abscess in the temporal lobe, and likewise the headache is localized in the occipital region when an abscess has its seat in the cerebellum. A peculiar rigidity of the head and neck, as well as pain in bending the head forward, are experienced with cerebellar abscesses. There is often a circumscribed point of tenderness on percussion in the corresponding parietal and temporal regions; still, this in itself is not characteristic for a brain abscess.

2. **Symptoms of increased pressure** are: Headaches, dizziness, vomiting, loss of memory, talkativeness, threatening those about them, delirium, strabismus, disturbances in speech and vision, slow pulse, optic neuritis, changes in the size of the pupils, stupidity (slow cerebration), apathy, somnolence, Cheyne-Stokes respiration, and eclamptic attacks associated with the peculiarly characteristic feature of the transient disappearance and recurrence of the above-mentioned symptoms. Oppenheim, as well as v. Bergmann, Macewen, and Barr, think that the slow pulse, which is absent in only a small number of cases, is the most important symptom. According to the clinical observations of the author, optic neuritis is found in only a small percentage of the cases, whereas a slight hyperæmia of the retina also occurs in cases of sinus thrombosis and meningitis. A well-marked choked disc, which is an important symptom in cerebellar

abscesses, is not often observed in abscesses of the temporal lobe.*

3. **Local symptoms in cases of brain abscess** do not often occur. Word-deafness (Ferrier, Horsley, Politzer, Van Gehuchten, and Goris), amnestic or optic aphasia (Oppenheim), and disturbances in speech, are principally observed in abscesses of the left temporal lobe, whereas in abscesses of the same lobe on the right side these symptoms are generally wanting. Sometimes an abscess in the temporal lobe is combined with a paralysis of the motor oculi nerve caused by pressure, with mydriasis and ptosis, or with an affection of the internal capsule; it is furthermore associated with paralyses, anæsthesia, or hyperæsthesia, more rarely spasms of the opposite extremities, crossed paralyses of the abducens and facial nerves, homogonous bilateral hemiopia (Körner), crossed facial and hypoglossus paralysis (Müller, *Archiv f. Ohrenheilk.*, vol. l.), and crossed hardness of hearing in the ear which was previously normal.

In the terminal stage, many symptoms of the active stage have disappeared, and in place of these there are marked symptoms of agony, irritability, and extreme restlessness, until coma finally sets in and death ensues.

Cerebellar abscesses, which sometimes commence with rigors, dizziness, and vomiting, run their course with various symptoms of irritation and pressure. Among the latter, which are made manifest by compression of the pons, the vermiform process, the medulla oblongata, and the cerebral nerves arising from the posterior cranial fossa, the following must be mentioned: Dysarthria and dysphagia, mechanical yawning, lockjaw (Monnier), paralysis of the facial nerve of the same side and unilateral paralysis of the pillar of the fauces (Thompson, Heimann, Politzer), pareses of the abducens (Katz), nystagmus towards the diseased side (Oppenheim), choked disc (Hansberg, Politzer), ptosis (Reier, Moos, Steinbrügge), glycosuria (Ulrich, Frey), paræsthesia in the extremities (Ceci), absence of the patellar reflex (Strümpel), general hyperæsthesia (Heimann, Lebert), disorders of the bladder, torticollis (Jansen), and cerebellar ataxia; this last-mentioned symptom is not infrequently observed, and is probably caused by an indirect action upon the vermiform process of the cerebellum (Nothnagel); still, it must be mentioned that it also occurs with other complications (Koch, Paulsen). By the indirect action of the cerebellar abscesses upon the pons and the medulla oblongata, we can explain the disturbances in gait (Koch) and the act of falling forwards (Dupuy). In several of the author's cases of cerebellar abscess, there were paresis and paralysis of the side on which the lesion was situated.

Course.—The course of brain abscess of otitic origin is very

* Lannois et Jaboulay, *L'hémianopsie dans les abcès cérébraux d'origine otitique* (*Rev. hel d. de laryng., d'otol. et de rhin.*, 1896).

irregular. In many cases it is latent, running a slow insiduous course without any striking brain symptoms. The violent symptoms sometimes develop several weeks or months before death takes place; however, these are seldom continuous, occurring in paroxysms, sometimes at longer and sometimes at shorter intervals. In other cases the violent cerebral symptoms develop only a few hours before death. Two cases of cerebellar abscess in the author's clinic showed no symptoms whatever during life, and ended suddenly in death as the patients were trying to sit up in bed.

The duration of brain abscess is often, owing to the abscence of marked symptoms, not ascertainable. Cases in which the violent symptoms arose shortly before death, showed, at the *post-mortem* examination, an old abscess surrounded by a connective-tissue capsule. When there are multiple abscesses, the changes in the tissue surrounding the abscesses show that they developed at different times.

Termination.—Brain abscesses of otitic origin generally end in death if not opened up by operative measures. Even in cases in which the abscess has been located and evacuated the ultimate result is doubtful, as many of the cases die of some other cerebral complication or a secondary meningitis. The cases described in literature of spontaneous cure by calcification or absorption of the contents of the abscess are extremely doubtful. In the publications of Bruns, Huguenin, Zimmermann, Wreden, Boucher, Wilde, Pollak, Gruber, and others. in which the brain abscess was supposed to have discharged externally, it is quite probable that the majority were extra-dural. There can be no doubt, however, that brain abscesses may discharge externally after an adhesion of the brain with the meninges and with the bone has taken place.

The fatal ending is caused either by meningitis after the abscess has ruptured on the surface of the brain, by encephalitis, or by rupture and discharge of the abscess into the ventricles of the brain. Finally, death may also be caused by œdema and compression of the brain, by paralysis of the respiratory and circulatory centres, by exhaustion, or by metastases in other organs.

Diagnosis.—The diagnosis of brain abscess of otitic origin is often very difficult; this is due to the uncertain course of the affection, and to a symptom-complex which is not infrequently ill-defined, and often entirely wanting. In the latent stage of the affection, every diagnostic aid is frequently wanting; whereas, on the other hand, after the appearance of violent symptoms, it is often impossible to differentiate it from the other otitic complications (meningitis purulenta, serosa and tuberculosa, extra- and intra-dural abscess). It happens especially often in children, and sometimes also in adults, that an uncomplicated

middle-ear suppuration may cause a symptom-complex which may be mistaken for a brain abscess, and all the more so if the otitis is complicated with an optic neuritis. This symptom is, however, by no means characteristic for meningitis or brain abscess. The difficulties presented by the differential diagnosis between brain abscess, circumscribed pachymeningitis, the different forms of meningitis, and labyrinthine suppuration, owing to the similarity of the symptoms, are apparent from the large number of patients observed during life, and from the condition of the brain and meninges found at the *post-mortem* examination. In many cases, a differential diagnosis can be made only after the appearance of marked symptoms. In a number of cases one is sometimes able (at least, with great probability) to make a diagnosis of abscess of the temporal lobe by certain marked symptoms, such as aphasia associated with a localized headache in the parietal region, tenderness on percussion, and increased temperature in the region of the affected half of the skull, or by the development of a crossed paralysis of the extremities. In like manner, there is little doubt that a cerebellar abscess is present if there is localized occipital or frontal headache associated with dizziness, ataxia, nystagmus, choked disc, hyperæsthesia of the scalp, and paralysis of the extremities on the same side.

The differential diagnosis between brain abscess and meningitis is often difficult; still, the experienced clinician not infrequently acquires many valuable diagnostic points from the impression which he gains at the bedside from the patient's behaviour. While the patient affected with a meningitis strikes one by his restlessness (picking at the bed-clothes, pulling at the bed-cover, attempts at escape, and screaming), the patient with a brain abscess is quiet and apathetic.

The symptoms for a differential diagnosis between cerebellar abscess and labyrinthine suppuration, especially the nystagmus, have already been discussed (p. 561).

That brain tumours and tubercles of the brain associated with a simultaneous middle-ear suppuration and marked local symptoms may easily be mistaken for brain abscesses is well known. Accordingly, attention must be called to the fact that paralyses of the nerves at the base of the brain are seldom observed with cerebral abscesses, while they are found, as a rule, with tumours at the base of the brain. The statement of Schulze, that uræmic symptoms with a co-existing middle-ear suppuration could be mistaken for a brain abscess, is confirmed by observations of the author. According to Oppenheim and Kümmel, a number of hysterical symptoms arising during the course of a middle-ear suppuration may also be mistaken for a brain complication of otitic origin.

Prognosis.—The prognosis of brain abscess of otitic origin,

which was absolutely unfavourable until some years ago, is now much more favourable since our technic for opening up a brain abscess by operative measures has been greatly improved. If, after laying bare the source of the pus and the removal of all the diseased tissue in the temporal bone, the abscess is evacuated and opened up freely before the appearance of serious complications, it is possible to obtain a cure in a considerable number of cases. According to Heine (*loc. cit.*), the abscesses lying near the dura offer the most favourable prognosis. To these we must also add the so-called cortical abscesses (Grossmann, *Archiv f. Ohren-heilk.*, vol. lxiv., and Kümmel, *Zeitschr. f. klin. Medicin.*, vol. lv.). Changes in the discs of the optic nerves should not always be regarded as an unfavourable symptom.*

The Operative Opening of Brain Abscesses of Otitic Origin.

The indications for the operative opening of brain abscesses are based on the diagnostic signs already mentioned. Although it must be admitted that the indications are limited by the difficulties of diagnosis, experience has, however, shown that an operative procedure should, nevertheless, be decided on in all cases in which (from the symptom-complex) the diagnosis of a brain abscess can be made with probability. At the author's clinic it was the rule that, if a labyrinthine suppuration had been established, and there were symptoms of a cerebellar abscess, the opening up of the abscess was carried out after the labyrinth had been laid bare (Neumann). When the diagnosis of a cerebellar abscess was not fully established, we awaited the result of the labyrinthine operation, and if the cerebral symptoms continued, we then proceeded to the opening up of the cerebellar abscess.

The prognosis of the operation is most favourable if it is performed at a time when the diagnosis of brain abscess is made from the long-continued headache localized in the parietal region (abscess of the temporal lobe), or in the occiput or forehead (cerebellar abscess), or if certain symptoms of paralysis (aphasia) make the presence of a brain abscess probable. The success of the operation is much more unfavourable if it is performed after the appearance of severe meningeal and brain symptoms, inasmuch as these generally allow us to conclude that a rupture of the brain abscess into the ventricle or on the surface of the cerebrum has taken place. That in some cases, even when this has occurred, the life of the patient may be saved is proved by the numerous cases of brain abscesses reported in literature

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* Cisneros, *Abcès cérébelleux d'origine otique* (*Bullet. de laryngol.*, Nos. 33 and 34, 1906); Emerson Linn, *A Case of Serous Meningitis mistaken for Brain Abscess—Recovery* (*The Laryngoscope*, July, 1906, p. 553).

which have been cured by operation. In cases, therefore, in which, from the symptom-complex or by the exclusion of other intracranial complications, we make the diagnosis of brain abscess of otitic origin, we must immediately proceed to evacuate it by operative means.*

The Operative Opening of an Abscess of the Temporal Lobe.

The operative opening of an abscess of the temporal lobe may be performed by two methods. The first consists in the direct exposure of the temporal lobe above the auricle by making a large periosteal flap in the skull, and the second in evacuating the abscess from the opened-up middle-ear spaces after a radical mastoid operation.

Experience has shown that abscesses of the cerebrum are mostly situated immediately above the tegmen tympani, and that it is therefore better to perform the operation for opening the abscess in conjunction with the radical mastoid operation (Körner). This method of operation, which v. Bergmann also advocated, is now generally preferred by the aural surgeon. The technical procedure is, briefly, as follows:

After chiselling open the mastoid process and opening the antrum in acute suppurations, or, in other words, after opening up the middle-ear spaces (radical operation) in chronic cases, the tegmen antri is removed, and the dura mater in the region of the posterior portion of the middle cranial fossa is exposed and explored for the presence of a brain abscess. If the dura is found to be unaltered, exploration of the brain abscess can be postponed, and undertaken only if, in the course of time, the cerebral symptoms do not disappear.

When the dura has been freely exposed, we can explore the brain in various directions by introducing a long, fair-sized puncture needle, which is connected with a large syringe. Sometimes we are fortunate in striking the abscess cavity immediately, while at other times we are compelled to introduce the needle repeatedly at different places, and even then are unsuccessful. If we have been fortunate enough to strike the abscess, which is evident by aspirating the pus into the syringe, we allow the needle to remain in place, and follow it up with a grooved director, whereupon the opening is enlarged with a pair of forceps or dilators and the pus given free vent.

If exploratory puncture has not been used, the exposed dura, which is covered with exudate or granulations, is incised as

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* Cp. Vinc. Cozzolino, *Indirizzo terapico-chirurgico nelle Complicanze intracraniche da flogosi purulente dell' apparato uditivo (Rassegna di scienze mediche*, 1892); Röpke, *Zur Operation des otitischen Grosshirn-abscesses mit besonderer Berücksichtigung des Heilwerthes der Operation (Z. f. O.*, 1898).

widely as possible; according to the procedure of v. Bergmann, a pointed bistoury (still better, the knife devised by Preysing, which is bent at right angles to the handle) is carefully introduced in a vertical direction 4 cm. into the brain substance, and by a slight turn of the instrument the brain is lifted for the purpose of allowing the pus to run off. In case we do not immediately strike pus, we can again introduce the knife into the brain substance in front of and behind the place of our first incision. That such incisions into the white substance of the brain may be made without danger has been frequently demonstrated by clinical experience.

After evacuating the abscess, the wound is kept open with a pair of dressing forceps until the pus is discharged by irrigating the cavity with a lukewarm, sterilized, normal saline solution, or peroxide. The danger of an eventual infection of the pia mater by the discharged pus, which is often foul-smelling and mixed with fœtid gases, occurs less often than was formerly supposed, inasmuch as bacteriological examination has proved that in cases of chronic brain abscess even the foul-smelling and fœtid pus loses its virulence.

After the pus has been washed out, the abscess cavity is loosely packed with sterile or iodoform gauze, which in the first few days must be changed daily, and less often in the further course of the affection. It has been found that it is more advantageous to use a small piece of rubber tubing or rubber tissue as a drain. Eulenstein recommends long-continued drainage, so that the cavity may completely fill with granulations. In order to inspect the abscess cavity after emptying its contents, we may use Whiting's encephaloscope· (*Trans. of the American Otol. Soc.*, 1903).

Prolapse of the brain through the wound, which is caused by increased brain-pressure or by an insufficient discharge of pus and gangrene of the prolapsed parts, are the most common incidents that may occur during the after-treatment.

The method of opening a brain abscess through the postoperative mastoid cavity has the advantage that the brain abscess is opened at its deepest part, and that the larger branches of the middle meningeal artery do not come into the field of operation.

A disadvantage of this operation is that, in case of faulty diagnosis, the opened-up dural space may easily become infected from the purulent affection in the middle ear.

The Operative Opening of a Cerebellar Abscess.

The operative opening of a cerebellar abscess, which is technically more difficult, can also be performed by two methods.[*]
One method consists in opening the posterior cranial fossa by

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[*] Grunert, *Ein Beitrag zur operativen Behandlung des otogenen Hirn-abscesses* (*Berl. klin. Wochenschr.*, 1896, No. 52); Kretschmann, *Beitrag zur Behandlung des otitischen Hirnabscesses* (*Münch. med. Wochenschr.*, No. 29, 1893).

entering the region between the sigmoid sinus and the posterior semicircular canal (Fig. 265) after the mastoid process has been chiselled away—in other words, after the radical mastoid operation. In this operation a part of the medial wall of the antrum, and the bone behind it, are removed. This method, which is used by most aurists, is preferable to all others, because the great majority of abscesses of the cerebellum are situated in the anterior and medial parts of the cerebellum, corresponding with the pathological changes on the posterior wall of the pyramid, and can therefore be reached and evacuated more readily from here (Okada).* We may count on reaching the abscess all the
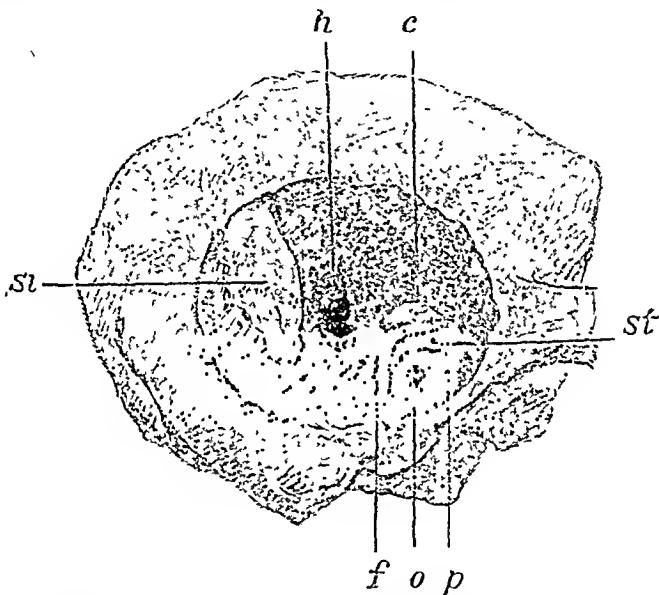
FIG. 265.—THE OPENED-UP MIDDLE-EAR SPACES IN A RIGHT TEMPORAL BONE.

d, Promontory; *st*, Stapes; *o*, Fenestra cochleæ; *f*, Facial nerve; *c*, Horizontal semicircular canal; *si*, The sigmoid sinus exposed; *h*, Opening between the semicircular canal and the sigmoid sinus for the purpose of opening an abscess of the cerebellum situated at a point corresponding to the posterior surface of the pyramid.

more easily if the bone between the semicircular canal and the sinus is softened by caries or perforated by a fistula (Koch, Macewen, Hansberg, Czerny, Frey), in which case the fistula enters directly into the abscess cavity. In such cases the parts surrounding the fistula are almost always adherent to the posterior wall of the pyramid.

* The limited space in a book of this nature renders it impossible to enter minutely into the details of the numerous methods proposed for opening cerebellar abscesses, and the author therefore refers the reader to Okada's monograph, which is in every respect exhaustive and instructive (*Diagnose und Chirurgie des otogenen Kleinhirnabscess in Dr. Haug's Vorträge*, vol. iii., Book X., 1900).

The size of the opening in the bone between the sigmoid sinus and the posterior semicircular canal varies in each case, ranging from 0·5 to 1·0 or 1·5 cm. As a rule, a triangular opening in the bone, 0·5 to 1·5 cm. in size, the point of which is directed downwards, is usually sufficient to enable one to see enough of the posterior cranial fossa. If the opening is too small, it may be enlarged anteriorly as far as the compact osseous tissue bordering on the posterior semicircular canal, and posteriorly by chiselling away the lateral wall of the sinus.

The second method, which is not used as often, is performed in the following manner: An opening, 3–4 cm. in size, is made in the occipital bone with a chisel or trephine 4–5 cm. behind the insertion of the auricle, and between the lateral and occipital sinuses, whereby the dura mater, as well as the cerebellum, is freely exposed. The objection to this method of operating is that the majority of cerebellar abscesses are situated medially, and it is therefore difficult to find an abscess in this part of the cerebellum from an opening in the occipital bone.*

After the dura has been exposed, we can explore the cerebellar region with a puncture needle as we do in the case of a temporal lobe abscess described on p. 589, and, if found, the abscess is opened up and drained. During the last few years, the best results were obtained at the author's clinic by introducing strips of iodoform gauze soaked with peroxide into the abscess cavity, as suggested by Neumann, especially in those abscesses produced by the anaerobic bacteria. We can also use a small piece of rubber tubing or, better still, a small strip of rubber tissue for a drain. As the abscess cavity becomes smaller, the drain is gradually reduced until it is finally withdrawn altogether.

The symptoms, after a cerebral or cerebellar abscess has been opened up, vary greatly. In some cases the effect of the operation is made evident by the rapid return of consciousness, and by the rapid or gradual disappearance of the severe cerebral symptoms. The symptoms produced by the inflammatory cerebral œdema, or by the reflex action of the abscess, such as disturbances in speech and pareses, disappear, as a rule, after the abscess has been successfully evacuated.

If there are no complications, and the case takes a regular course, the abscess cavity fills with granulations, and cicatrization usually results within three to six weeks. The middle-ear suppuration may subside, but sometimes continues even after the abscess has healed.†

* Cp. Paul Koch, *Der otitische Kleinhirnabscess*, Berlin, 1897.

† Cp. Barkan, *Zeitschrift f. Ohrenheilk.*, vol. xxxiii.; Barr, *Zeitschrift f. Ohrenheilk.*, vol. xxxiii.; Heiman, *Zeitschrift f. Ohrenheilk.*, vol. xxiii.; Holger Mygind, *Archiv f. Ohrenheilk.*, vol. lxv.; Schmiegelow, *Archiv inter. de laryng.*, etc., 1905; Schwabach, *Festschr. f. Lucae*, 1905; Steinhaus, *Münchener med. Wochenschr.*, vol. xxxvii., 1905; Villard et Leclerc, *Lyon méd.*, p. 373; Frey, *Wiener med. Presse*, 1905; Köbel, *Med. Korresp.-Bl. d. württ. ärztl. Ver.*, 1905; Lobenhoffer, *Inaug. Diss.*, Erlangen, 1905; Moure, *Soc. franç. d'otolog.*, 1905.

A fatal result after the operation may be caused by different complications. As such must be mentioned: A diffuse encephalitis or gangrene of the brain substance, acute œdema of the brain, metastatic abscesses in the other parts of the brain, meningitis, pyæmia, infection of the wound, and general paralysis due to pressure on the medulla oblongata. Inasmuch as the cerebral pressure is increased by the anæsthetic, Milligan (*Zeitschr. f. Ohrenheilk.*, 1905) recommends lumbar puncture before the operation for cerebellar abscesses.

If the results of brain abscess operations are collected, it will be found that there is a greater percentage of cured cases than those which have ended fatally. The results, however, would be less favourable if, as experience has shown, we would take it into consideration that some of the patients who are discharged as cured die later of the sequelæ of the brain abscess or from other otitic complications.*

The general treatment of brain abscess is purely symptomatic. Narcotics may be given if the patients complain of pains or severe headaches, or display great restlessness, and stimulants may be necessary (camphor, ether, alcohol) if there are signs of depression.

The Diseases of the Sinuses of the Dura Mater Secondary to Otitis.

Of the venous channels running along the temporal bone, the sigmoid sinus, coursing on the inner surface of the mastoid process, is most frequently involved in the purulent affections of the mastoid bone; the superior and inferior petrosal sinuses, the cavernous sinus, the bulb of the internal jugular vein, and the venæ diploïticæ (osteomyelitis), are less often affected.

Arthur H. Cheatle† describes as the sinus petro-squamosus a venous channel which is not constant, and is very variable in its course (Fig. 266); it lies in a sulcus in the middle cranial fossa, empties into the sigmoid sinus, and often reaches the external surface of the skull through a canal of the temporal bone and zygomatic process. According to Cheatle, this sinus brings about the anastomosis between the veins of the middle ear and those of the meninges; this may explain the extension of a purulent affection from the middle ear to the cranial fossa without macroscopic changes in the osseous walls of the temporal bone. Other paths of invasion are the internal auditory vein and the veins of the aquæductus, by which the infection is transmitted to the inferior petrosal sinus; and also the emissary veins of the mastoid, by which the infection is carried to the sigmoid sinus. Infection of the sinuses of the temporal bone can also be produced by an extradural abscess (Kramer, *Zeitschr. für Ohrenheilk.*, vol. liv.).

* On healed cases of cerebellar abscess there are further reports from U. Pritchard, *Z. f. O.*, vol. xxii.; Manasse, *Z. f. O.*, vol. xxxi.; Lichtenberg, *Gesellsch. d. ungar. Ohren. u. Kehlkopfärzte*, 1897: Waggett, Sixty-seventh Annual Meeting of the British Medical Association, Portsmouth, 1899; Frey, *Archiv f. Ohrenheilk.*, vol. lx.; and *Wiener med. Presse*, 1905; Neumann, *loc. cit.*

† *Transactions of the Sixth International Otological Congress in London*, 1899, London, 1900.

The inflammatory diseases of the venous sinuses of the temporal bone, which develop in acute and chronic middle-ear processes, arise from extension of the purulent infection in the bone to the wall of the sinus. If, in acute middle-ear suppuration, the suppurative inflammation advances as far as the wall of the sigmoid sinus, an encapsulated purulent inflammation between the sulcus and the sinus wall is brought about, which leads to the formation of a perisinous abscess. This in turn brings about an inflammation of the external layer of the sinus wall, with symptoms of high fever, and as the affection progresses there develops an inflammation of the intima, which leads to the formation of thrombi, pyæmia, emboli, and finally death, if the perisinous abscess is not opened in time. In addition to the continuous high fever, the affection becomes evident by pain on
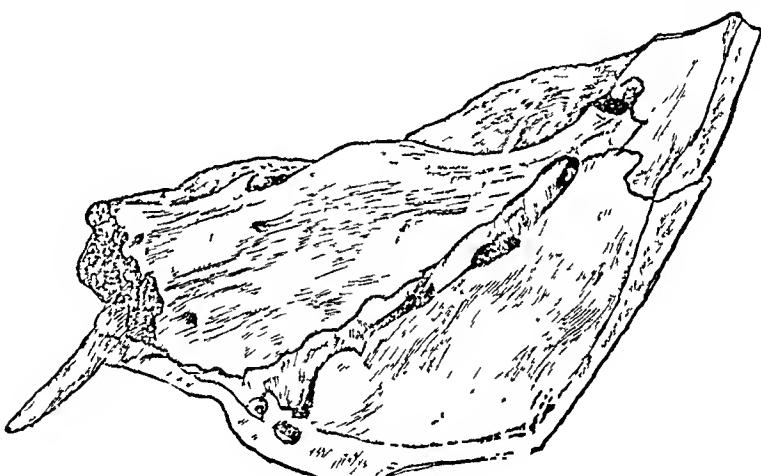
FIG. 266.

pressure at the posterior border of the mastoid process over the emissary vein; and, in the further course, by an œdematous swelling at this place.

Conditions are different when, in acute or chronic middle-ear suppurations, an extensive destruction of the bone takes place, by which the sinus wall is exposed to a varying extent. In this case, one often finds at the operation, the exposed sinus bathed in pus and covered with a layer of fibrin or granulations, without giving the least sign of a sinus affection during the entire course of the disease. This fact is corroborated by the experiments on animals carried out by Stenger (*Deutscher Otologentag*, 1904), who regards the wall of the sinus itself as the best guard against an infectious thrombus.

When, in an infectious otitis, or in cario-necrotic processes, the inflammation has extended to the interior of the sinus, its wall appears thickened, brownish yellow, discoloured, raised from the underlying bony surface by the pus

ichorous matter, hæmorrhagic extravasate, or by caseous greasy masses, and covered with crusts of exudate or granulations; at times it is ulcerated and perforated by fistulæ. The inner wall of the sinus is inflamed, swollen, covered with masses of adherent blood, which give it a villous appearance, perforated or destroyed. The sinus contains thrombi, which adhere to its walls or block its lumen, and which are either solid or show signs of purulent or ichorous degeneration; the thrombi sometimes extend, on the one hand, down through the jugular vein to the subclavian vein, and, on the other, to the confluence of the longitudinal and lateral sinuses, and from there to the lateral sinus of the other side. In like manner, the phlebitis may extend, on the one hand, from the sigmoid sinus to the inferior and superior petrosal sinuses and cavernous sinus, and, on the other hand, to the emissary veins of Santorini. As a rule, however, the thrombus extends downwards to the bulb of the internal jugular vein, and into the vein itself. When cario-necrotic defects are found in the bone, the surrounding area appears discoloured, softened, and affected by osteoporosis, while the other parts are covered by net-like osteophytes.

Otitic sinus thrombosis often runs its course without any other intracranial complications. At times, however, it is combined with extradural abscess, meningitis of the posterior cranial fossa, diffuse leptomeningitis, cerebellar and, less frequently, cerebral abscess.*

According to Lebert, Hessler, Jansen, and Forselles, sinus thrombosis affects males three and a half times as often as females; the right sinus is more frequently affected than the left. Whether this depends on the greater width of the right sinus—a fact which was already known to Morgagni—is difficult to say.

In the suppurative sinus phlebitis a general septicæmia (sepsis) often develops, owing to a transmission of the bacteria (bacterœmia) or their toxines (toxæmia) in the blood-channels. In other cases symptoms appear which are caused by the formation of metastatic abscesses (pyæmia).

Symptoms.—The symptoms of otitic sinus affections depend on whether we have to do with a sinus thrombosis which is or is not associated with a pyæmia or septicæmia. The uncomplicated sinus phlebitis may run its course without symptoms; in the majority of cases, however, it arises with vomiting and headache, and with mild cerebral and meningeal symptoms of irritation. The true pyæmic cases of sinus thrombosis are characterized by severe chills and fever, with its characteristic marked remitting course, and by emboli and metastases in other organs; the true cases of septicæmia,† which are much more seldom, are characterized by the continuous high fever, various exanthemata of the skin, and hæmorrhages, but particularly by the symptoms of a general infection (delirium, vomiting, cyanosis, icterus, dilated pupils, weak pulse, dry tongue, cardiac collapse, and coma). It not infrequently

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* Alderton, *Thrombosis of the Lateral Sinus with Mastoid Abscess* (*Medica Record*, New York, 1897).

† Cp. Eulenstein, *Zeitschr. f. Ohrenheilk.*, vol. xl.

happens that the symptoms of septicæmia and pyæmia are combined (septico-pyæmia) (Kümmel).

In the pyæmic sinus thromboses there are usually remissions of the fever, in which the temperature sinks below normal, followed again, after several hours, by a sharp rise to 39° to 40° C. (102·2° to 104° F.) and over, with or without rigors. In the last stage of the disease the chills are much more frequent, so that often several chills are observed during the day. The pulse is accelerated, being often so weak that it cannot be counted, and at the same time very small and of reduced tension; the skin is dry, and after the illness has existed for several days, slightly icteric; the tongue is dry and coated, the spleen is enlarged, and consciousness is clear to the end. In addition to these, there is usually a marked euphoria. The head seldom feels constricted or painful. Symptoms which appear less frequently are vomiting, stiffness of the cervical muscles, and optic neuritis observed by Kipp (*Z. f. O.*, vol. viii.) in 8 per cent., and by Jansen (*A. f. O.*, vol. xxxvi.) in 50 per cent. of the cases.* A symptom of diagnostic importance, but one which does not always accompany thrombosis of the sigmoid sinus, is an œdematous swelling on the mastoid in the neighbourhood where the emissary veins enter the sinus, which at times spreads to the temporal region and to the eyelids. That thrombi have formed and have extended from the sinus to the internal jugular vein is made evident by the appearance of a tough band on the side of the neck in the course of the jugular vein, which is very painful on pressure. It not infrequently happens that a marked œdema or a tense phlegmonous infiltration develops in the neighbourhood of the thrombosed jugular vein. If a thrombus extends to the bulb of the internal jugular vein and exerts pressure on the hypoglossal, and on the vagus, glosso-pharyngeal, and spinal accessory nerves which emerge from the jugular foramen, or if a periphlebitis of the bulb develops *ex contiguo*, symptoms of irritation, and later of paralyses of these nerves, will be brought about in the form of hoarseness, cough, a vagus pulse, etc.†

Kümmel regards a pain during the act of swallowing, without apparent changes in the pharynx or larynx, as a valuable diagnostic symptom of phlebitis of the bulb. He thinks this is due to a neuritis or perineuritis of the glosso-pharyngeal nerve, which passes through the jugular foramen.‡

In cases in which the thrombosis extends to the emissary veins (Orne Green,

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* Lermoyez, *Un signe de la thrombose du sinus longitudinal supérieur* (*Annales des mal. de l'or.*, 1897).

† Beck, *Deutsche Klinik*, 1863; further, Stacke and Kretschmann, *A. f. O.*, vol. xxii.; Schwartze, *Deutsch. militärärztl. Zeitschr.*, 1890; Kessel, *Dissertation*, Giessen, 1866; Wreden, *A. f. A. u. O.*, vol. iii., 2; Ludewig, *A. f. O.*, vol. xxx.

‡ *Mitt. aus d. Grenzgeb. d. Med. u. Chir.*, 1907.

Macewen, Forselles), one finds on the mastoid process, a painful infiltration and induration of the subcutaneous and subfascial connective tissue, which reach to the cervical region.   In like manner, œdema of the eyelids and face occurs in cases in which the thrombus extends from the jugular to the facial vein.   In those rare cases in which the sinus petro-squamosus is persistent, an œdema in the temporal region (Moos, *Z. f. O.*, vol. ii.) is observed. Gerhard's symptom (*Deutsche Klinik*, 1857), which consists of the unequal filling of both jugular veins upon compression, is not constant.

The symptom-complex of sinus thrombosis is complicated if the thrombi in the superior and inferior petrosal sinuses extend to the cavernous sinus.   The most important symptoms of thrombosis of the superior petrosal sinus are: Swelling of the veins in the temporal region, thrombosis of the retinal veins (Politzer), epistaxis, and epileptiform attacks.   If the thrombi extend to the cavernous sinus there occurs, in consequence of the formation of a thrombus in the ophthalmic vein, engorgement of the vessels of the orbit, disturbances of vision, photophobia, paralysis of the motor oculi, abducens and trochlear nerves, exophthalmos, ptosis, œdema of the eyelids, sloughing of the orbital tissue, and neuralgia of the trigeminus.   This symptom-complex is generally so characteristic that the diagnosis of thrombosis of the cavernous sinus may be made with certainty.

In extensive thrombosis of the sigmoid sinus, the thrombus may extend beyond the confluence of the longitudinal and lateral sinuses, and bring about a thrombosis of the superior longitudinal sinus, especially in its posterior part.   Lermoyez (*Ann. d. malad. d. l'oreille*, 1897) saw, in one of his cases, swelling of the veins of the scalp; Gradenigo (*Archiv f. Ohrenheilk.*, vol. lxvi.) observed a painful, fluctuating swelling in the median line of the vertex of the head.   One of the rarest cases is that reported by Kretschmann (*Archiv f. Ohrenheilk.*, vol. l.), in which a sinus thrombosis extended through the torcular Herophili and the inferior petrosal sinus of the opposite side into the cavernous sinus, and produced symptoms of thrombosis of the cavernous sinus on the opposite side.

Course and Terminations.—The course of sinus thrombosis is very irregular.   The process sometimes takes a very rapid course, inasmuch as death takes place within a few days with symptoms of collapse, or by the formation of metastases in other organs; sometimes, however, the course is slow, so that single attacks of rigors are followed by shorter or longer intervals in which the state of the patient's health is apparently normal, until finally, after several weeks or months, the patient dies from a general septicæmia or a pyæmia.*

The termination of sinus phlebitis, if left to itself, is, with but few exceptions, fatal.   Death most frequently takes place from a metastatic pleuro-pneumonia, from septicæmia, or from gangrene of the lungs (Hessler), more rarely from an abscess of

* Bojew, *Quelques cas le pyohémie d'origine otitique* (*Revue hebd. de laryng.*, etc., 1898); Langworthy, H. G., *Thrombosis of the Cavernous Sinuses* (*Boston Medical Journal*, 1906).

the lungs, nephritis, or metastases in the subcutaneous connective tissue, in the joints, in the periarticular tissue, in the brain (Kruckenberg, Pitt), and in the larynx (Ballance). At times, however, a fatal result is caused without the formation of meta- stases by the high fever (septicæmia). Death has been known to occur from the excessive hæmorrhage which follows erosion of the sinus.

The ultimate result of sinus phlebitis depends partly on the local changes in the temporal bone and partly on the infectious character of the thrombi. If, after the formation of a thrombus, the pus in the neighbourhood of the sinus is removed by operation, and the clot is not septic, a cure may often result owing to its absorption or by its change into connective tissue; this occurs more frequently in acute than in chronic cases.* This fact has been proved by *post-mortem* examinations in which organized thrombi in the sigmoid sinus have been found in individuals who, during their life, showed no symptoms whatever of a sinus affection. The same termination has also been observed in cases in which there were severe pyæmic symptoms; in these cases cure took place by an obliteration of the sinus through connective tissue formation.

A cure of this affection without an operation is rare. We cannot state positively that the case is one of cured sinus throm- bosis for the reason that the appearance of rigors, high fever, and even pain along the jugular vein by no means allow us to come to this conclusion. Even cases such as Prescott-Hewett (*Lancet*, 1861) describes as cured, in which, besides rigors, there were metastases in the joints and in the lungs, should not be taken as cured cases of sinus thrombosis, because a similar symptom- complex without a sinus affection can also be caused by the immediate absorption of septic matter from the spaces of the temporal bone into the circulation. To these we may also add the observations of Hessler, Körner, Broschniowski, Zaalberg, Massier, Luc, and Remini, of cases which sometimes run a favourable course with chills and metastases, and which can be traced to an osteophlebitis of the temporal bone.

Diagnosis.—The diagnosis of otitic sinus phlebitis and throm- bosis may be made with probability if, during the course of an acute or a chronic middle-ear suppuration, or after a mastoid operation, repeated attacks of rigor develop, which present the picture of a severe general infection, and which are associated with high fever, followed by remissions below the normal tem- perature (pyæmia). There can be no doubt as to the diagnosis if,

* R. Hoffmann, *Ein Fall von Sinusthrombose mit bindegewebiger Obliteration des Sinus sigmoideus* (*A. f. O.*, vol. l.); Warnecke, 2 *Fälle von Sinusthrombose mit bindegewebiger Obliteration des Sinus sigmoideus* (*A. f. O.*, vol. xlviii.); Zebrowski, *Zur Frage der Heilbarkeit und operativen Behandlung der otogenen Pyämie* (*Monats. für Ohrenheilk.*, vol. xl., January, 1907).

in addition to these symptoms, one notices a painful cord-like induration along the course of the internal jugular vein, as already mentioned, a difference in the size of the two external jugular veins, an œdematous swelling in the region of the mastoid, especially in the region of the emissarium (Griesinger's symptom), or in the posterior triangle of the neck, and metastases in the joints and other organs. The diagnosis is more difficult in the course of an acute otitis, because the symptoms, which are often severe during pus retention (fever, feeling of cold, pain, and œdema over the mastoid), may easily hide the symptoms of a sinus thrombosis; and all the more because cases of sinus thrombosis occur, which run an irregular course with an irregular temperature curve, without chills, and with mild mastoid symptoms. Leutert, therefore, assumes that a fever continuing several days after the subsidence of the acute stage, and accompanied by a free discharge of pus from the tympanic cavity, points to the diagnosis of sinus thrombosis in an acute otitis.*

During the last few years our diagnosis of sinus thrombosis has been greatly facilitated by the examination of the blood. In doing this we take into consideration the presence or absence of septic micro-organisms, which is ascertained by making smears and cultures of the blood taken from the patient's arm. Too great importance cannot be attributed to the outcome of such an examination, as it is only by this means, in a large number of cases in which all other symptoms leave us in doubt, that we are able to arrive at a diagnosis of an infection of the lateral sinus.

Sinus thrombosis, as we well know, is a rather common complication of a suppurative otitis media or mastoiditis, and is usually accompanied by a definite chain of symptoms which allows one to assume that one is dealing with such a condition; yet one occasionally meets with cases in which all symptoms point to an infection of the sinus, and yet one hesitates to operate until one has learned the result of the blood examination. The reason for this is that other infectious diseases may at times be associated with an aural affection, and may give rise to a similar symptom-complex, the sinus being absolutely free from any septic condition. It is, therefore, in these cases that a thorough examination of the blood is so essential, and in most cases helps us out of our difficulty in clearing up the diagnosis. In all cases in which there is, or was, a history of an aural affection, whether of brief or long duration, and in which the temperature shows marked fluctuations ranging from 99° to 104° or 105°, with or without chills, and all other infections can be excluded, it is advisable to make a blood-test. If such an examination

* Voss gives as a sign of complete thrombus of the jugular vein, that the venous noise heard in the normal state when a stethoscope is placed against the vein is no longer heard when the sinus is occluded.

reveals the presence of micro-organisms, we can then say with a fair amount of certainty that we are dealing with a septic focus having its seat in the lateral sinus, and we are thereupon justified to resort to operative measures to lay open this source of infection. In order to detect the presence of bacteria in the blood, we make smears and cultures. Even in cases in which there is a septic focus in the sinus, the examination of the blood by these methods leaves us often in doubt, as it is not always possible to obtain a positive result. That in such cases the result of the smear or culture may at times be negative is explained on the generally accepted theory that, in a case of bacteriemia of pyogenic origin in which there is a distinct focus of pus, bacteria may be disseminated into the blood-stream from the original focus only at certain intervals, these crises manifesting themselves clinically by chills, sweats, and very high temperature. In such cases the bacteria are often demonstrated only at the height of the fever. That the bacteria can be seen in the smears of the blood was clearly pointed out by the investigations of Fried and Sophian,[*] who showed that in 97 per cent. of the cases of sinus thrombosis in which the blood-culture was positive the bacteria could be discovered in the blood-smear. This method has the advantage in that it can be performed quickly, whereas the blood-culture requires from twelve to forty-eight hours. This time-saving factor is extremely valuable, as the sooner the diagnosis is established, the earlier can one resort to operative interference for opening up the septic focus, and the greater are the chances for recovery. There is, therefore, little doubt as to the value of blood-smears in suspected cases of sinus thrombosis.

The result of the blood-culture alone, in the majority of cases, gives us positive data in allowing us to conclude that we are dealing with a case of sinus thrombosis, and in justifying us to explore the sinus for some septic focus. Of the different bacteria, the one which is of vital interest in sinus thrombosis is the *Streptococcus hemolyticus*. This micro-organism, when found in the blood, allows us to assume with justice that we are dealing with a suppurative focus in the sinus. In making a culture of the blood we are interested to learn whether these hemolytic streptococci are present or not; in other words, whether our findings are positive or negative. A positive result is, in the great majority of cases, indicative of an involvement of the sinus; yet a negative finding does not by any means exclude such a condition. Libman,[†] in 1908,

* Libman, *The Value of Bacteriological Investigations in Otology, with Special Reference to Blood Cultures* (Arch. Otol., vol. xxxvii., 1908); Libman; E., *A Further Communication on the Importance of Blood Cultures in the Study of Infections of Otitic Origin* (Tr. Ninth Internat. Cong., Boston, August 12-17, 1912).

† Fried, G. A., and Sophian, A., *Investigations Concerning the Value of the Microscopic Examination of the Blood for Bacteria* (Am. Jour. Med. Sc., vol. cxlii., 1911, p. 88).

demonstrated conclusively by laboratory findings that in those cases in which there was a history of an aural affection, and the blood-culture was found to be positive, a thrombosis of the lateral sinus was invariably present. His investigations, furthermore, showed that sinus thrombosis and meningitis are the only otitic complications giving rise to a general bacteriemia. That these findings are correct has been substantiated by similar results obtained in a large number of blood-cultures made in such cases, and by the conditions found at the time of operation. For, in the ten cases in which operation was performed in the otologic service of Mount Sinai Hospital by Gruening,* and in another series of cases reported by Oppenheimer,† the blood-culture was positive in nearly every instance, and a septic thrombus was found at the time of operation.

One must not forget, however, that even in cases in which a thrombus of the sinus is present, the blood-culture is not always positive at the first examination. According to Libman,‡ this may be due to the fact that the blood-culture may have been taken before a bacteriemia has been established, or the bacteria may be in the blood in such small numbers that they are not found in the amount of blood taken for the culture. It may also happen that below the infected clot there may be another obturating uninfected clot which prevents the bacteria entering the circulation, or there may be an infected thrombus completely closing the lumen of the vessel.

For these reasons, it is generally advisable, when an involvement of the sinus is suspected, to make repeated examinations of the blood. The fact that the blood-culture is negative at one time and positive at another may, perhaps, also be explained by the fact that the bacteria are disseminated into the blood-stream at certain periods, and, as stated before, in particular during the height of the fever.

Meningitis and brain abscess are apt to be mistaken for this disease only if the sinus affection appears simultaneously with these intracranial complications (Macewen's meningeal type of sinus affection). The differential diagnosis in such a case is made clear by the result of the lumbar puncture. If there are no intracranial complications, the differential diagnosis is made all the more easily, inasmuch as the symptom-complex of uncomplicated sinus phlebitis differs entirely from that of brain abscess,

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* Gruening, *Six Cases of Thrombosis of the Lateral Sinus operated upon in the Ear Ward of Mount Sinai Hospital in the Course of the Past Winter* (*Tr. Am. Otol. Soc.*, 1906); *Sinus Thrombosis of Otitic Origin and its Relation to Streptococchœmia* (*N.Y. Med. Jour.*, June 5, 1909).

† Oppenheimer, *Some Remarks on Sinus Thrombosis, with Particular Reference to the Diagnostic Value of Blood Cultures in Otitic Disease* (*Ann. Otol., Rhinol., and Laryngol.*, March, 1911).

‡ Libman and Celler, *Importance of Blood Culture in the Study of Infections of Otitic Origin* (*Am. Jour. Med. Sc.*, December, 1909).

and especially meningitis. While in meningitis and brain abscess such severe rigors and high temperatures never occur, one finds, on the other hand, in sinus thrombosis that the brain symptoms are only slightly marked, and that the consciousness of the patient is clear nearly to the final coma. Contrary to meningitis, there is usually a marked euphoria. Confusion with typhoid fever, malaria, and miliary tuberculosis is possible if the presence of an ear affection is overlooked. According to Hinsberg, sinus thrombosis can run its course with the symptoms of an acute articular rheumatism.

Prognosis.—The prognosis of otitic sinus affections—thanks to the great progress which modern surgery has made in the last few years—is very favourable, especially if the diagnosis is made early and the infected focus is opened up freely by operative measures. The prognosis is rather unfavourable when metastases have already developed, when there are symptoms of a meningitis or brain abscess, and when thrombosis of the cavernous sinus is manifest. According to the author's experience, the sinus affections which run their course with metastases in the subcutaneous tissue or in the joints take a more favourable course; the sinus affections arising during the course of an acute otitis are more favourable than those arising during the chronic forms.

The Operative Treatment of Sinus Phlebitis of Otitic Origin.

The main object of the operative interference in otitic sinus phlebitis is to prevent the invasion of the bacteria and their toxines into the circulation by a thorough removal of the infected seat of suppuration.

Laying bare, or, in other words, opening up, the sigmoid sinus is indicated in all cases in which the symptoms already mentioned are present, and in which the aural affection runs its course with continuous high or remittent fever, whether it is associated with rigors or not. In acute mastoiditis associated with continuous high fever, the sinus should always be laid open, when opening up the mastoid abscess, in order to see if there is a perisinous abscess.

Exposure of the sinus is performed after the mastoid process has been opened up (p. 500), or, in other words, after the radical mastoid operation.

The cavity of the opened mastoid process is widened posteriorly, and the bone over the sigmoid sinus is removed in layers, until a small portion of the membranous sinus wall is exposed. The sinus is more easily reached if the sigmoid sulcus in the temporal bone is pushed far forwards and outwards. In removing the sinus wall, one must use great care not to injure or tear the

membranous wall. This can be best avoided by not using a chisel, but by removing the bone carefully with a small bone forceps or rongeur.

If an opening has been made in the sigmoid sulcus, it is widened superiorly as far as the knee of the sinus, and inferiorly to the jugular foramen until the sinus is laid bare to a sufficient extent.

If the wall of the sinus is normal, it is of a dark blue colour, and usually presents a distinct pulsation, which, according to Mann (*Deutscher Otologentag*, 1904), increases if the head of the patient is well turned towards the opposite side. If there is a perisinous abscess, the pus will immediately force its way through the opening in the sulcus when the bone has been taken away. The exposed wall of the sinus appears yellow, discoloured, thickened, uneven, and covered with granulations, but rarely shows an ichorous degeneration. Granulations and layers of exudate are found in protracted cases of otitis without a diseased condition of the intima. If the sinus does not pulsate and is resistant to the touch, one may suspect the presence of thrombi; pulsation, however, may still continue if a flat clot is adherent to the intima of the wall of the sinus. In several cases of sinus thrombosis the author noted a pulsation of short duration immediately after exposure of the sinus, which undoubtedly was caused by the small arterial vessels surrounding it.

Bönninghaus and Hammerschlag consider an empty, collapsed sinus—that is, one which cannot be differentiated from the dura mater—a sign of markedly increased cerebral pressure.

A method proposed by Whiting for the diagnosis of a clot in the bulb of the internal jugular vein or below it, is called by him 'expression experiment.' It consists in compressing with the left index-finger the sigmoid sinus close to the bulb of the internal jugular vein; the right index-finger is then placed immediately alongside the left, and moved in a stroking manner upwards towards the knee of the sinus, where it is firmly held. By this procedure the blood is pressed out of the collapsed sinus. If the pressure with the left finger is now removed, and if blood does not enter the sinus from below, it may be concluded that there is an obliterating thrombus in the bulb of the internal jugular vein, or in the vein itself. If, on the other hand, blood enters the sinus when the right index-finger is removed, it is a proof that there is no obliterating thrombus above.

The nature of the contents of the sinus is ascertained either by aspiration or by an exploratory incision. To perform aspiration it is well to use a large needle and a medium-sized syringe. It is advisable to introduce the needle into the lumen of the sinus at an acute angle rather than at a right angle, for by doing so one avoids penetrating the inner wall of the vessel. This procedure has the advantage that one can readily ascertain the nature of the sinus contents without incising its wall. Of course it may happen that one obtains a quantity of blood at the place

of puncture, and is made to believe that the sinus is patent and free from infection, while in reality there is a septic thrombus above or below which does not entirely obliterate the lumen of the vessel. The incision is, according to the author's observations, harmless, and to be preferred to the exploratory puncture, because adherent thrombi, which do not occlude the lumen of the vessel, can be more readily discovered in the majority of cases by this means. Before incising the sinus wall, we introduce a small roll of iodoform gauze firmly between the bone and sinus wall above and below. The wall of the sinus is then incised, and
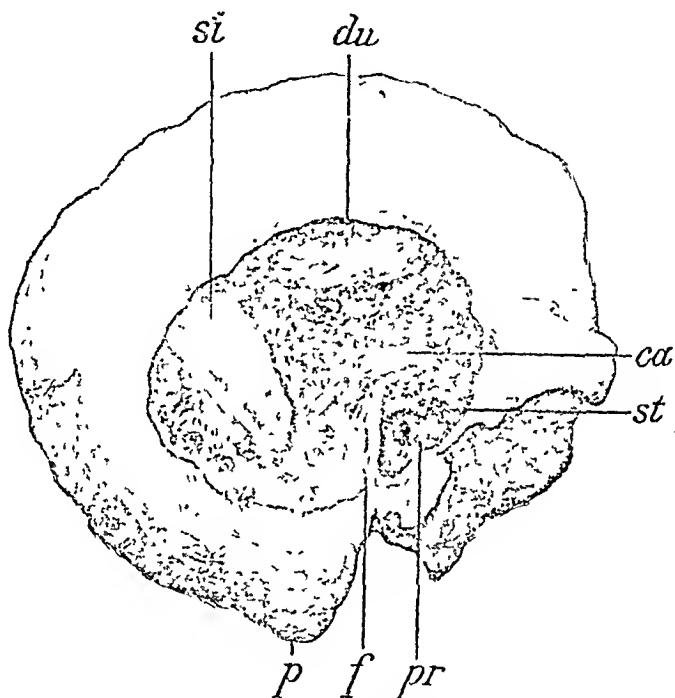
Fig. 267.—A Specimen showing the Exposed Middle-Ear Spaces with the Dura Mater and Lateral Sinus Laid Bare.

du, The exposed dura mater; *si*, The exposed lateral sinus; *pr*, Promontory; *f*, Descending part of the facial canal; *st*, Stapes; *ca*, Prominence of the horizontal semicircular canal; *p*, Mastoid process.

the sinus widely laid open. If thrombi are found, they are removed with a pair of forceps or a curette, and the masses followed upwards until fluid blood begins to flow freely. In like manner we follow the clot downwards until we get a free return flow from the bulb. Having obtained a free gush of blood from both ends, the wound is packed tightly. It is usually seen that that part of the thrombus corresponding to the carious part of the sulcus is especially infectious, and that sometimes noninfectious coagula adhere to this thrombus both above and below it, thus forming a protective wall against the extension of the

infectious material into the circulation. In spite of this, all the thrombosed masses must be thoroughly removed, as one can never tell macroscopically whether they are infectious and how far they extend above and below.

Softened or gangrenous parts of the sinus are removed, and the wound packed with iodoform gauze. The after-treatment is the same as that of the radical operation (*vide* p. 543).

The danger of air being aspirated is out of the question if the internal jugular vein is ligated before opening up the sinus. This may happen, however, if the vein is not ligated first, and, is favoured, according to Senn, by an extensive loss of blood, by the head of the patient lying too high, and by a sudden deep inspiration.*

In cases of perisinous abscess, the result of the operation after laying bare the sinus is most favourable if, at the time of the operation, the inflammation of the venous wall has not yet led to the formation of septic thrombi within the sinus. In such cases the dangerous symptoms often disappear shortly after exposing the sinus. Sometimes, however, in spite of the fact that the wound is running a favourable course, remittent attacks of fever continue for some time. The result, after removing the septic thrombi, is most favourable if the thrombosis is limited to the sigmoid sinus, and extension of the infection is prevented by the formation of non-infectious thrombi above and below the infected focus.†

It is only in recent times that the practical importance of ligation of the jugular vein in otitic sinus thrombosis has been universally recognized. There is still a great difference of opinion as to the indication and time of ligation.

Bergmann, Forselles, Lane, Zaufal, and others advocate, as a rule, ligation of the vein before opening the sinus, but only, however, in cases in which a septic thrombosis is found after the sinus has been exposed. By ligating the vein, septic material and particles of the thrombus which have been loosened by the operation are prevented from entering the blood-stream. Jansen thinks that ligation of the internal jugular vein is indicated if rigors and fever continue after the removal of the thrombi. Macewen ligates the jugular vein only if the thrombosis extends so far down that it can no longer be reached from the opened sinus; Horsley only when metastases are present, in order to check their further development.

The jugular is ligated before the mastoid operation when the diagnosis is positively established; when the diagnosis is doubtful, however, we ligate only after exposure, or eventually after exploratory puncture or incision of the sinus; if the sinus contains blood, ligation must be performed only if the pyæmic symptoms continue after removal of the primary seat of infection.

* Edgar Meier, *Ueber Luftembolie bei Sinusoperationen* (*A. f. O.*, vol. xlix.).
† Shephard, *Transactions of the American Otological Society*, Thirty-first Annual Meeting, 1898; Castex, *Bull. de laryng.*, etc., T. II., 1899; Heiman, Congress at Moscow, 1897; Voss, *Archiv f. Ohrenheilk.*, vol. xxxix.; Moure, *Phlébite suppurée du sinus latéral et ligature de la jugulaire; considérations anatomo-cliniques* (*Revue hebd. de laryngol. et d'otologie*, etc., No. 3 January 19, 1907).

Ligation of the jugular vein is carried out as follows: After thoroughly cleansing the field of operation, an incision about 6 cm. in length is made at the level of the annular cartilage of the trachea through the skin and platysma muscle along the anterior border of the sterno-clcido-mastoid muscle; the internal jugular vein is bluntly dissected out of its sheath, ligated above and below in its healthy portion, and then resected between these ligatures. If the ligature is introduced below the vena facialis communis, this must then also be ligated above. It is well to ligate the facial vein in nearly every case. If the thrombosis has extended into the jugular vein, a large piece of the vein lying between the ligatures should be resected, according to Parker and Horsley. At the author's clinic, in every case in which the thrombosis extends into the bulb of the vein, and after section of the doubly ligated vein, Alexander splits the upper end of the vein and sews it into the wound in the neck, in order that it may act as a drainage tube (jugular skin fistula). By this procedure it is often possible to remove the thrombi in the bulb and in the vein itself by careful irrigations from below. If the jugular thrombosis reaches far down, a resection of the clavicle may become necessary (Zaufal).

The question frequently arises whether it is better to excise or to ligate the vein. It has been the writer's experience, and it seems to be the consensus of opinion of other observers, that excision is always preferable. This is based on the fact that almost every case of sinus thrombosis is associated with a phlebitis of the jugular vein. If, therefore, the vein is only ligated, it is difficult to tell macroscopically at the time of the operation how far the phlebitis extends, and, as often happens, a part of the infected vein remains below the ligature, which serves as a means of reinfection of the blood.

The favourable results of ligation of the jugular vein reported in literature cannot be put down with certainty as the result of this operation, inasmuch as a cure is also often obtained after removal of the infectious material from the sinus without ligation of the vein.* That, in spite of ligation, septic material from the infected area in the sinus may reach the general circulation through the collateral venous channels is doubtful. Opposition has been raised against ligation of the jugular vein before opening up the sinus, for the reason that, in cases in which the sinus is not completely thrombosed, a return flow of the blood towards the venous channels of the cranium is brought about by the ligation, through which the superior and inferior petrosal sinuses and the larger venous blood-channels of the cranial cavity may become infected. If there is danger that the newly formed thrombi lying above the place of ligation of the vein may enter the collateral channels, the jugular must be opened up above, as far as possible from the place of ligation, and its contents, as well as that of the bulb, cleaned out from below.

Zaufal deserves the credit of having been the first to suggest the operative treatment of sinus thrombosis (*Prag. med. Wochenschr.*, 1891).

The operative opening of the transverse sinus was first performed in England with favourable results by Lane in 1888 (*British Medical Journal*, 1889). Chas. A. Ballance (*The Lancet*, 1890) followed him with a large number of sinus operations. The result of this operative measure in otitic sinus affection is, considering the severity of the disease, a very favourable one.

A cause of the continued pyæmic symptoms after clearing out the sigmoid sinus was often found to be due to a thrombosis of the bulb of the jugular vein. In such cases it is advisable to open up and curette out the bulb, as first proposed by Grunert. This method of Grunert has been modified by Piffl, Voss, Laval, and Neumann. Grunert follows the sinus from the opened-up mastoid

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* Heine, *Operationen am Ohre*, 1906; Knapp, A., *Primary Cavernous Sinus Thrombosis Secondary to Osteomyelitis of the Petrous Pyramid* (*Archives of Otology*, October, 1906); Bronner, A., *An Unusual Case of Thrombosis of the Lower Part of the Lateral Sinus* (*The Lancet*, 1906).

process down to the bulb, and exposes this by taking away the osseous ring forming the jugular foramen. In this way the sinus, bulb, and jugular vein are laid open in one uninterrupted line, and favourable conditions created, so that drainage takes place externally. By this method there is, however, great danger of injuring the facial nerve. Piffl, after detaching the auricle and pushing back the periosteum, lays the bulb open by removing the posterior, inferior, and also a portion of the anterior walls of the external meatus by way of the recessus hypotympanicus. In using this method the bony ridge forming the jugular foramen remains standing, whereby the facial nerve is less likely to be injured; the conditions for drainage are more unfavourable than in the Grunert method.

Voss exposes the bulb from the medial side by way of the mastoid cavity; he takes away the bony mass in the region of the posterior inferior angle of the pyramid covering the bulb.

Neumann removes the external ridge of the jugular foramen by means of a Gigli saw, which is drawn through the bulb.

Tandler (*Monat. f. Ohrenheilk.*, 1908) devised a method by which he exposes the bulb of the jugular vein directly from without, at the same time dissecting out the spinal accessory and facial nerves. By turning up the sterno-cleido-mastoid muscle backwards and outwards, the place where the accessory nerve* enters the muscle becomes visible (Zuckerkandl). After chiselling away the lower end of the mastoid process, and detaching the biventer muscle from the sulcus biventericus in the bone, the foramen stylo-mastoideum, with the facial nerve, comes into view, and marks the boundary up to where the bone can be chiselled away step by step. The main object of this method of operating is that, through exposure of the spinal accessory nerve and the extra-cranial portion of the facial nerve bordering immediately on the stylo-mastoid foramen, these nerves are visible during the entire operation, and are thereby protected against injury.

The results published thus far of the bulb operation are not very satisfactory because, if performed even with the utmost care, it is often accompanied by extensive and permanent injury to the facial and spinal accessory nerves. According to the author's opinion, the bulb operation is unnecessary in the majority of cases, on account of the jugular skin fistula method proposed by Alexander, and should be performed only in the most urgent cases. The variable position of the bulb, and its abnormal extent upwards towards the semicircular canals and the internal meatus, naturally excludes an operative method which is suitable for all cases.

The internal treatment of sinus thrombosis running its course with pyæmia or septicæmia consists in the administration of large doses of quinine, salicylate of soda (2–3 grammes a day), and antipyrin (0·5 to 1·0 gramme a day). At the same time, we must endeavour to keep up the general strength of the patient. Inunctions of Credé's silver ointment on the back or on the lower extremities have been recommended, but have not proved very beneficial.

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* According to Tandler's investigations, the nerve crosses the jugular vein ventrally in two-thirds, and dorsally in one-third of the cases.

Fatal Hæmorrhage from the Middle Ear in Consequence of Erosion of the Internal Carotid Artery.

The fatal termination of a middle-ear suppuration by excessive hæmorrhage from erosion of the internal carotid artery is extremely rare. Cases are reported in literature from time to time in which the diagnosis of erosion of the internal carotid artery is made, and confirmed by the *post-mortem* examination.

Anatomy. — Examination of these cases shows that the portion of the carotid canal adjoining the tympanic cavity is more or less necrotic and defective. The perforation in the carotid canal is either free or still occluded by sequestra. The perforation in the arterial wall, which is generally softened, is always found at the spot where the course of the vessel changes its direction from the vertical to the horizontal. In the two cases observed by Baizeau (*Gaz. des Hôp.*, 1881, 88) and Choyau (*Arch. Gén. de Méd.*, 1866) the carotid artery was perforated in two places; in all other cases, a tear in the arterial wall, 3–8 mm. in length and 2–6 mm. in breadth, is usually found. The edges of the tear are usually jagged and fringed, more rarely clean cut, as if an incision had been made. A direct communication between the tympanic cavity and the eroded artery could be demonstrated in every case. In the case described by Busch and Santesson (*Schmidt'sche Jahrb.*, 1862) the lateral sinus was also simultaneously eroded. In every case the blood poured through the perforated tympanic membrane into the external meatus, except in the case reported by Pilz, in which the membrana tympani was intact, and in which the blood escaped by a fistulous opening in the inferior wall of the tympanic cavity into an abscess cavity in the petrous portion of the temporal bone, and from there escaped by another fistula into the pharynx.

The majority of cases were in tuberculous individuals; in one case scrofula, in another secondary syphilis, and in one case cauterization with concentrated acids, were given as causes of the middle-ear suppuration.

In several cases, erosion of the carotid artery was complicated with circumscribed pachymeningitis, basilar and cortical meningitis, and brain abscess.

Erosion of the carotid artery is no doubt caused by an inflammatory softening of the arterial wall, which is surrounded by pus and ichor, whereby its power of resistance is so diminished that the repeated concussions of the blood-waves finally cause a rupture.

An aural affection has been known to exist from seven to eleven years or more, before erosion of the artery took place, which was accompanied by a more or less copious hæmorrhage; only in two cases, is the suppuration supposed to have existed for

several months. In a case of syphilis observed by Pilz, the hæmorrhage occurred during the course of an acute caries.

Symptoms.—As a rule, the flow of blood from the ear is profuse, and not always of a pulsating character. In some cases only a continuous oozing is observed, while in other cases the blood rushes from the ear with such force that it forms a thick stream, which is arrested with extreme difficulty. The amount of blood which is lost during a violent hæmorrhage varies from 240 to 1,500 grammes. In the majority of cases the blood is bright red. Sometimes the blood escapes at the same time through the Eustachian tube into the pharynx, and the patient (by swallowing the blood) has hæmorrhagic stools. In cases of profuse hæmorrhage, there may be marked anæmia associated with a general collapse.

The number of hæmorrhages before a fatal issue varies from one to three, four, seven, and even twenty (Toynbee, *Diseases of the Ear*, 1860).

The duration of each hæmorrhagic attack varies from four to ten minutes; in one case the hæmorrhage lasted seven hours (Broca-Jolly, *Arch. de Méd.*, 1866), and in another six days, with an intermission of barely twenty-four hours (Hermann, *Wien. med. Wochenschr.*, 1867). The period from the commencement of the first hæmorrhage to the fatal issue varies from five minutes to thirteen days. In the author's case, in which ligation of the carotid was not permitted, death took place after eight hæmorrhages, and eleven days after the first hæmorrhage. In the cases which were operated upon, death occurred once three days, and once four weeks, after ligation of the carotid. In Pilz's case, which was operated on by Billroth (erosion of the right carotid), death took place seventeen days after ligation of the right, and three days after ligation of the left, internal carotid artery.

Every case ended fatally from profuse hæmorrhage and from general exhaustion.

Diagnosis.—The diagnosis is made by the bright-red colour of the arterial blood, and by the cessation of the hæmorrhage on compression of the carotid artery. There can be no doubt that the bleeding comes from the carotid artery when the blood spurts from the ear in great gushes, and synchronous with each systole of the heart. If the hæmorrhage is not very severe, it is possible that it might come from an erosion of the middle meningeal artery (Ward, *Trans. of the Pathol. Soc.*, 1846), or from some other small branches of the carotid. Bleeding from the lateral sinus may be distinguished from a hæmorrhage of the carotid artery by the fact that in the former, the blood is dark red and continues to flow after compression of the carotid.

Prognosis.—Judging from the cases published up to the present, the prognosis is absolutely unfavourable.

Treatment.—In every hæmorrhage from the ear, which is of such a nature as to lead to the suspicion of an erosion of the carotid artery, we must first endeavour to stop the hæmorrhage by compression of the common carotid artery, and at the same time to pack the external canal and middle ear as firmly as possible. The attempt to stop the hæmorrhage may be attended with success only if compression is continued without interruption for some time. It is important to instruct the person in charge of the patient how compression should be applied, so that in the event of a recurrence of the hæmorrhage before the arrival of the physician a great loss of blood may be avoided.

If compression of the artery does not stop the hæmorrhage, the common carotid artery must be ligated. In a case operated upon, in which nine days after ligation of the carotid hæmorrhages from the ear, mouth, and nose recurred, ligation of the other carotid had to be resorted to; still, in spite of this, death occurred three days later during another hæmorrhagic attack. Although, in the small number of cases hitherto observed, ligation of the carotid artery has never saved the life of the patient, still the possibility of a successful issue is by no means excluded, if the local changes in the neighbourhood of the eroded artery prove to be more favourable, and if the obliteration of the carotid by a thrombus (caused by the ligature) is made possible. Whether, in the case described by Denucé (*Bull. de l'Acad.*, 1878) of recovery from an arterial hæmorrhage from the ear by ligation of the carotid, the cause of the bleeding was due to an erosion of the internal carotid artery is a moot question. In regard to the technique of the operation, the reader is referred to the larger manuals of surgery.

The introduction of a tampon into the external meatus, which prevents the rapid gush of blood from the ear for the time being, proves, however, useless, inasmuch as the blood rapidly forces its way through the Eustachian tube into the naso-pharynx.

That, in middle-ear suppurations, a diseased condition of the wall of the carotid artery with the formation of a thrombosis may be brought about, has been observed in a few rare cases. Cerebral emboli and softened areas of the brain have been observed as sequelæ.

Erosion of the other cerebral sinuses is rather unusual in middle-ear suppurations. According to Eulenstein (*Zeitschr. f. Ohrenheilk.*, vol. xliii.), erosion of the sigmoid sinus is met with most frequently in the chronic scarlatinal middle-ear processes.[*] Cases have been reported of hæmorrhages from the superior and inferior petrosal sinuses, from the sinus caroticus, from the cavernous sinus, and from the bulb of the jugular vein. The hæmorrhage which arises from the superior petrosal sinus and from the emissary mastoid veins can be arrested by tamponing.

* Lebram (*Zeitschr. f. Ohrenheilk.*, vol. l.) reports two cases of spontaneous hæmorrhage, as a result of an erosion of the sigmoid sinus, in scarlatinal otitis.

NEW FORMATIONS IN THE SOUND-CONDUCTING APPARATUS.

I. Connective-tissue New Formations.

A. On the Auricle.

Of the connective-tissue growths occurring on the auricle the fibroma, the keloid cicatrix, and the myxofibroma are most frequently observed.* They develop, as a rule, on the lobule, as a result of piercing the ears, and are supposed to occur especially often in negro women, who have a special predisposition towards the formation of fibromata. Their growth is slow and painless. The growths often attain an enormous size, and occasionally involve the entire auricle.

As a rule, fibroma of the lobule is a bilateral affection, but may, however, be of unequal size on the two ears. It appears as a globular, semi-globular, or lobulated, partly movable tumour, which is more or less solid, and consists for the most part of fibrous connective tissue mixed with a myxomatous substance. Fibroma of the auricle is a benign growth, inasmuch as after its total extirpation a recurrence seldom takes place.

The treatment consists in the extirpation of the tumour, care being taken to produce a scar which does not disfigure the auricle.

Angiomata of the auricle are more rarely observed. They appear as bluish-red tumours, which pulsate more or less, attain the size from a lentil to that of a walnut, and are situated at the external auditory orifice, on the lobule, or on the posterior or anterior surfaces of the auricle. Multiple angiomata of the auricle and in its neighbourhood have been described by Turnbull (London Medical Congress, 1881) and Mussey (*Am. Journal of Med. Sciences*, 1853).

Angiomata are either congenital or may arise after the auricle has become frozen. Their growth is sometimes slow, sometimes very rapid. The ectatic dilated condition of the vessels sometimes extends to the meatus, to the region around the ear, and to the scalp. When the growth of angiomata is gradual, scarcely any disturbances are noticed; when, on the other hand, their growth is rapid, there are often throbbing pains in the affected parts. By rupture of the dilated vessels severe hæmorrhages may occur, which may even lead to a fatal termination. Warnecke observed in Lucae's clinic the varicose veins of pregnancy in the form of bluish-red tumours in front of, above, and behind

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* Knapp, *Archiv f. Augen- und Ohrenheilk.*, vol. v.; Turnbull, London Med. Congress, 1881; Finley, *Philadelphia Med. Times*, ix.; Bürkner, *A. f. O.*, xvii.; Habermann, *A. f. O.*, xviii.; Arslan, *Revue hebdom. de laryngol. et otolog.*, 1899.

the concha and in the auditory canal; Haug (*A. f. O.*, vol. xxxii.) observed, in one case, an angiomatous new formation on the lobule, which surrounded a tubercular nodule.

The **treatment** of angiomata depends on the size and extent of the growths. When they are small and flat, it is advisable to draw several aseptic silk threads dipped in chloride of iron through the tumours; these threads are allowed to remain in order to coagulate the contents of the tumours and cause them to shrivel up. This method is, at all events, preferable to cauterization with nitric acid or scarification. By the rational use of the Paquelin thermocautery, cure will be much more quickly and surely effected than by any other method of treatment. When the tumours are small, the operation may be completed at one sitting; but when the tumours are large and vascular, it is better to cauterize only a small part at a time at intervals of from five to six days. The reason for this is to avoid the formation of large crusts, as a reactive inflammation associated with a marked secondary hæmorrhage may readily occur. If there are large arteries near the auricle which lead to the angioma, they must be ligated first before excising the growth. Ligation of the carotid artery is indicated as a last resort only when, in spite of the repeated application of the thermocautery, the growths recur and are associated with very severe uncontrollable hæmorrhage.

B. In the External Auditory Canal and in the Middle Ear.

Aural Polypi.

The pedunculated, connective-tissue growths in the ear, known as polypi, which develop in the course of the chronic, less frequently in the acute, middle-ear suppurations, and in primary inflammations of the external auditory canal, arise most frequently from the mucous membrane of the middle ear, less often in the external meatus and on the membrana tympani.

They arise most frequently from the inner and inferior walls of the tympanic cavity, from the covering of the ossicles, and from the external attic; more rarely from the cells of the mastoid process, and the mucous membrane of the Eustachian tube. In the external auditory canal, the polypi spring mostly from the posterior superior wall of the osseous meatus in the neighbourhood of the membrana tympani. Polypi in the external auditory canal develop either from the superficial or deep layers of the cutis, or from the periosteum. On the membrana tympani, the polypi usually arise from the posterior superior portion, from Shrapnell's membrane, and occasionally from the edges of a perforation or paracentesis opening. Sometimes, polypoid growths are found simultaneously in the middle ear, on the membrana

tympani, and in the external auditory canal. The occurrence of polypi in the tympanic cavity without perforation of the membrana tympani has been proved by the observations of Zaufal and Gottstein (*A. f. O.*, vol. iv.).* One or more polypi may occur in the same ear. When there are (Fig. 268), several polypi, which were originally separated, they may unite into one, owing to long-continued contact.
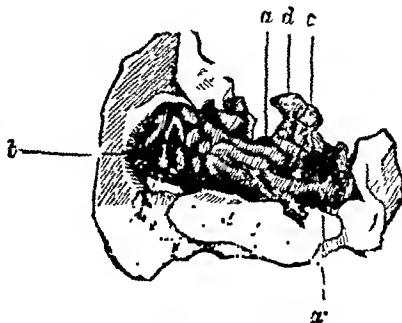
FIG. 268.

b, Polypus; *c*, *d*, Remnant of the malleo-incudal body; *a*, Root of the polypus adherent to malleus and incus; *a'*, Second root of the same polypus springing from the inner and lower walls of the tympanic cavity.
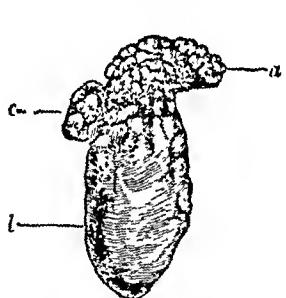
FIG. 269.—FIBROUS POLYPUS OF THE EXTERNAL MEATUS.	FIG. 270.—FIBROUS POLYPUS OF THE EXTERNAL MEATUS.	FIG. 271.—KNOB-LIKE BRANCHED POLYPUS OF THE TYMPANIC CAVITY.
a, Root; *b*, Body of the polypus; *c*, Several hard excrescences growing on the root of the polypus. Avulsion with Wilde's snare.	*a*, Root; *b*, Body of the polypus; *c*, Round excrescences the size of a hemp-seed on the posterior section to the polypus. Avulsion with Wilde's snare.	*a*, Root.

The size of aural polypi varies from the size of a pea to that of a date-kernel; still, they may attain a size greater than the length of the external auditory canal (Fig. 269). In such cases the tumour projects beyond the external orifice of the ear.

The form of polypi is either long or club-shaped; more rarely globular or knob-like (Fig. 271). Their surface is smooth or lobulated, glandular and raspberry-like. In the neighbourhood

* Kirchner, *Ueber Ohrpolypen* (Inaug. Diss., Munich, 1876).

of the root of large and smooth polypi one frequently finds a number of papillary excrescences (Figs. 270, 271). The growths have either a broad base, or a thin, pedunculated root.

Structure of Aural Polypi.—When aural polypi are examined histologically, two principal forms are generally found—round-celled polypi and fibromata. True myxomata (Steudener), or tumours composed principally of epithelial tissue (Weydner), are rare.*

The round-celled polypus consists of a hyaline, homogeneous stroma traversed by a more or less well-developed fibrous framework, in which scattered or closely packed round cells, and sometimes a few spindle cells, are embedded (Fig. 272, *d, d'*). By metamorphosis of the round cells
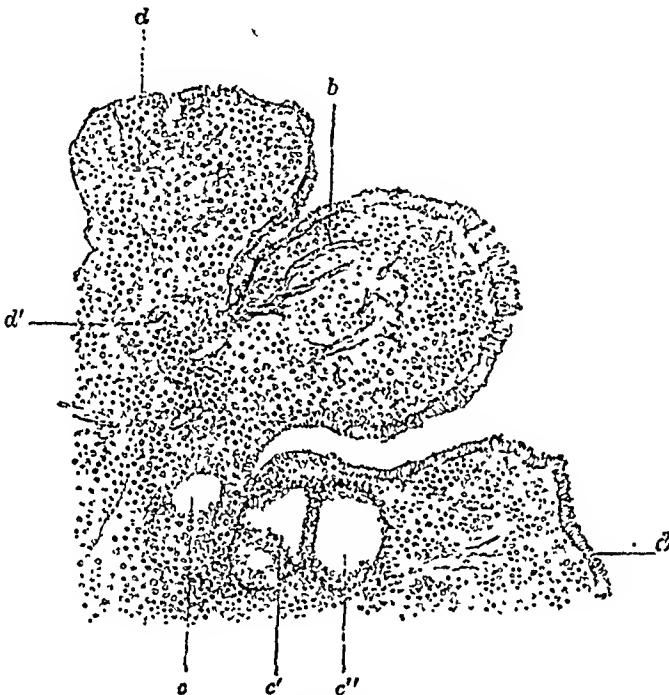
FIG. 272.

into spindle cells, the soft polypus attains a hard, fibrous character. This change usually proceeds irregularly from the root to the body of the polypus. The surface of these polypi is seldom smooth, but mostly of a glandular papillary nature, having deep gland-like indentations (Fig. 272), or true glands. The surface of these growths is covered with an epithelium which shows all the transition stages from simple ciliated epithelium (polypi of the tympanic cavity) and pavement epithelium (polypi of the auditory canal) to the complicated epithelium of the mucous membrane of the mouth. The polypi of the tympanic cavity are also at times covered with squamous epithelium. A combination of different forms of epithelium on one and the same polypus—that is, the ciliated variety in the region of the root, and pavement epithelium in other parts of the growth—is not rare. In the interior of the polypus, enclosed cavities lined with epithelium (*c, c', c''*) as well as cyst-like spaces (Steudener's retention cysts) are often found. These cysts may become so large that the entire polypus is composed of a single cystic space.

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* Wägenhäuser, *Zur Histologie der Ohrpolypen* (*A. f. O.*, vol. ix.. 1884).

The occurrence of cysts containing cholesteatoma in the polypi, as observed by the author, is confirmed by Goerke. Cysts containing giant cells have been described by Manasse (*Z. f. O.*, xxxiii.). Aural polypi containing hair have been described by Krepuska (*Ges. d. ungar. Ohren. u. Kehlkopfürzt*, 1897) and Brieger. Circumscribed and diffuse disintegration or fatty degeneration is not uncommon. Brühl (*Z. f. O.*, 1900) found in polypi, which bore resemblance to granulation tissue, the following kinds of cells: polynuclear leucocytes, fibroblasts, formative cells of the bloodvessels, giant cells, fat cells, and very many Unna's plasma cells; the latter he regards as coming from the leucocytes. Hahn and Sacerdote (*Archiv f. Ohrenheilk.*, vol. lxv.) found numerous plasma cells. Goerke observed sebaceous and cerumenal glands in a polyp of the meatus.

True fibromata have a fine, long-fibred, fibrillated stroma (Fig. 273), in which spindle cells are often interspersed. They are not so rich in bloodvessels as the round-celled polypi. Their surface is usually smooth and covered with
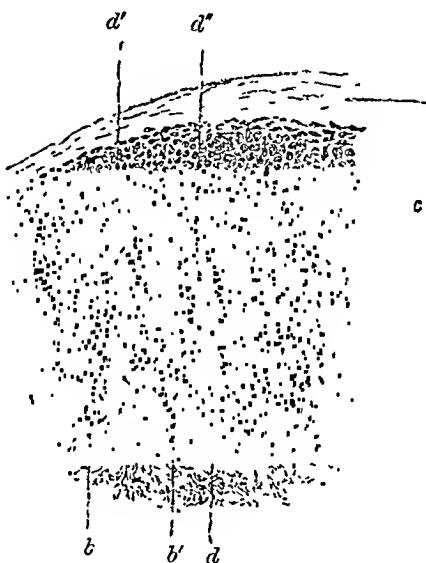
FIG. 273.

stratified pavement epithelium (*c*), the uppermost layers of which (*a*) are cornified. The epithelium (*c*) penetrates the tissue of the polypus (*d, d', d''*) in the form of long cones (*b, b'*). In tuberculosis of the middle ear, tubercle bacilli have at times been found in the polypoid granulations. Brühl (*Zeitschr. f. Ohrenheilk.*, vol. xlix.) reports a fibroma of the external meatus which was rich in glands.

Some polypi of the tympanic cavity are traversed by numerous bloodvessels, and thus assume the character of cavernous polypi or angiomata. By marked development of the interstitial tissue during their growth, the bloodvessels are so contracted that they partly atrophy, whereby, in longitudinal sections, the polypus has a striated appearance. Combined forms of angiofibroma and angiomyxofibroma have been described by Klingel. A few nerves have been found in the growths, and then only in their pedicles.

In a few rare cases, branching osseous trabeculæ have been found in the tissue of the polypus. As the ossification occurs principally near the place of attachment of the polypus, it is probable that the osseous trabeculæ extend into the tissue of the polypus from the bony walls of the meatus. Isolated ossification and calcification of aural polypi are rarely seen. A case of aural

polypus observed by Morpurgo and the author is worthy of mention. The patient was a man who died of general osteomalacia, and in whom, at the first examination, a round-celled aural polypus was found; several years later, when the polypus was removed, it proved to be an osteosarcoma, in which there was an extensive network of bone. The *post-mortem* examination showed that the polypus originated from the upper portion of the inner wall of the tympanic cavity.*

The growth of fibromata proceeds, as a rule, very slowly, while that of round-celled polypi is much more rapid. The author observed a case in which, two days after the removal of a polypus from the tympanic cavity, a second, transparent, round-celled polypus, 3 cm. long and 5 cm. thick, appeared. The development of polypi without suppuration in the ear is extremely rare; the author has only once observed, several years after a suppuration of the middle ear had run its course, the development of a hard, bluish-red tumour the size of a pea on the superior wall of the meatus near the membrana tympani.†

Symptoms and Terminations.—Aural polypi may exist a whole lifetime without causing any symptoms. At times they are accompanied by repeated hæmorrhages from the meatus, but as a rule they are associated with a more or less purulent discharge. Owing to the mechanical obstruction to the escape of secretion, they occasion unilateral headaches, a feeling of pressure and heaviness in the affected side of the head, tinnitus, dizziness, vomiting, spasmodic contractions, and epileptiform attacks. In the majority of cases they are the cause of the fœtid purulent secretion, and are often the underlying factor in causing the chronicity of the aural affection.

In a case of Schwartze's (*A. f. O.*, vol. i.) a unilateral paresis and anæsthesia of the extremities of the affected side were cured by the extirpation of several aural polypi. In two cases reported by Schmiegelow (*Revue mens. de laryng. et otol.*, 1887), the removal of aural polypi was followed by a cure of the neuroses, which were of a reflex nature. In the first case the neurosis manifested itself by spasmodic movements and anxiety; in the second case, by melancholia and homicidal insanity. Suarez de Mendoza (*Revue mens. de laryng.*, 1888) saw recovery take place, in a case of epilepsy which lasted a long time, after the extirpation of aural polypi; Hillairet, the disappearance of erections and attacks of dizziness. Not infrequently, by the stagnation of secretion, condensed caseous masses are formed, which may, by decomposition, lead to caries of the bone and to fatal complications.

Recovery by the spontaneous shrivelling up of the polypi, which seldom occurs, is produced by the growth of the endothelial cells in the bloodvessels; on the other hand, spontaneous mortification and the discharge of a polypus with a small pedicle, very often take place if the vessels in the root are constricted by torsion of the growth. At times polypi with broad bases are also cast off in consequence of gangrene for which there is

* W. Kiselbach, *Beitrag zur Histologie der Ohrpolypen* (*Monat. f. Ohrenheilk.*, 1887).

† An excellent paper on the histology of aural polypi, with splendid illustrations, has been published by Bosio in his monograph, *Ricerche istologische sui polipi della cassa del tympano*, Empoli, 1902.

no demonstrable cause. Termination in atresia of the meatus by adhesion of the polypus to the walls of the auditory canal has already been described (p. 237).

Diagnosis.—As a rule, the diagnosis of aural polypi is not very difficult, and is readily made on inspection. Only in rare cases is it possible to confound these growths with a strongly bulging membrana tympani deprived of its epidermis (*vide* p. 351), with exostoses covered with inflamed cutis (p. 235), with granulations growing out of fistulæ in the meatus, and with those malignant neoplasms which protrude from the tympanic cavity in the form of polypi (see later). The rapid recurrence after repeated removal of the growths, the co-existent infiltration of the neighbouring lymph-glands, and especially the appearance of sections under the microscope, soon reveal the nature of the growths.

As regards operative treatment, it is very important to find the place of origin of the polypus, as the manner of procedure is essentially different according to whether it grows from the external auditory canal, the tympanic membrane, or the middle ear. In the case of a small, long or thin polypus it is often possible, with the use of the probe, to ascertain its place of origin. In those cases, however, in which the polypus fills the entire meatus and only its outer end is visible, the finding of its root is much more difficult. The author uses a blunt probe curved at a right angle, the outer end of which is marked off in spaces of 5 mm. in order to measure the distance of the root from the external orifice of the ear. The examination is carried out as follows: The point of the probe is introduced between the polypus and the wall of the meatus, and while the instrument is passed around the growth it is gradually advanced into the deeper parts. When the instrument reaches an obstacle which prevents its circular movement, it may be assumed that this obstacle is the root of the polypus.

In those cases in which an obstacle is met with at a depth less than 16 mm., it may be justly assumed that the root of the polypus arises in the external auditory meatus. In cases in which the obstacle is reached at a greater depth, the location of the root can no longer be positively ascertained. By means of the circular movements of the probe it is also sometimes possible to ascertain the width of the root of the polypus. The greater this distance, the broader the root. If the polypus is found to be very movable, it is quite probable that the growth possesses a narrow and thin pedicle; if, on the other hand, the growth is but slightly movable, it may be assumed that the root is broad. In exceptional cases, a polypus growing from the tympanic cavity may be adherent to the walls of the meatus, and thus simulate a polypus of the meatus.

When there is a large perforation of the tympanic membrane, and the polypus does not fill the whole opening, the growth may be traced into the tympanic cavity (Fig. 274) with the careful use of the probe. If, however, the polypus is closely

surrounded by the edges of the perforation and constricted, the differential diagnosis between a polypus of the membrane and of the tympanic cavity is made more difficult. In such cases only the removal of the growth and the eventual view of the perforation will reveal the seat of the polypus. When there are polypi of the tympanic cavity which are hidden by the remnant of the membrana tympani or by the wall of the attic, the author has repeatedly been successful in bringing a part of the growths into view by rarefying the air in the external meatus with Siegle's speculum. In large defects of the tympanic membrane, the author was also able to diagnose the presence of polypi in the attic by means of the small tympanic mirror (p. 413).
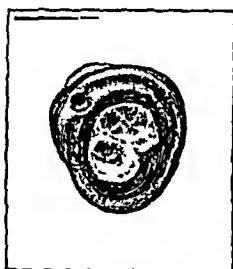
FIG. 274.—POLYPUS OF THE TYMPANIC CAVITY GROWING THROUGH THE PERFORATION.

In a girl, aged sixteen, who had suffered from otorrhœa for one year. Acoumeter = 2 m.; whispered speech = 6 m.

Another, though not a certain, guide for ascertaining the seat of polypi is the external appearance of the growths. The pale red, pearl-gray polypi, which are covered with pavement epithelium, and have a smooth or moderately uneven surface, usually grow from the external auditory canal, while the sodden, red, vascular, raspberry-shaped growths, which have a nipple-like papilliform surface, and are covered with ciliated epithelium, usually arise from the tympanic cavity. These peculiarities, however, are of diagnostic value only if taken in conjunction with the results of examination with the probe.

Prognosis.—The prognosis is more favourable with polypi of the meatus, inasmuch as their radical removal is more readily accomplished than with polypi of the tympanic cavity, which, as is well known, frequently recur if their roots are situated in the depressions of the tympanic cavity, which are inaccessible to instruments. The following conditions make the prognosis unfavourable: The formation of caseous, septic masses in the deeper parts of the ear which is associated with simultaneous painful caries of the temporal bone, marked symptoms of pus retention, and the development of symptoms indicative of a pyæmic or cerebral complication.

Treatment.—(1) Operative Treatment.

(a) **Avulsion.**—This method of treatment is indicated only in those cases in which the aural examination shows that the polypi have their seat in the external auditory canal. Avulsion is much more certain of success and quicker than the other methods of

operation in which the polypus is either cut off or ligated. In the latter method, the destruction of the remaining fibrous roots requires a period of several weeks or months, whereas after avulsion, by which the root is generally removed with the growth, the suppuration often ceases within a few days. In addition to this, a recurrence is not so often observed after avulsion as after excision or ligation, inasmuch as by the latter methods, the root of the growth must be destroyed by subsequent cauterization.

Before removing an aural polypus the external auditory canal is cleansed by syringing, and then filled with a 3 or 5 per cent. solution of cocaine to which a few drops of adrenalin have been added, and allowed to remain for five or ten minutes. By this procedure the operation for the removal of the growth may be performed almost without pain and with a very slight loss of blood. Frey proposed a method, by which he injects a few minims of a 1 per cent. cocaine solution, to which adrenalin solution has been added, directly into the polypi. This procedure is much more reliable and is usually free from pain. It works particularly well with large growths and is not accompanied by any unpleasant sequelæ.
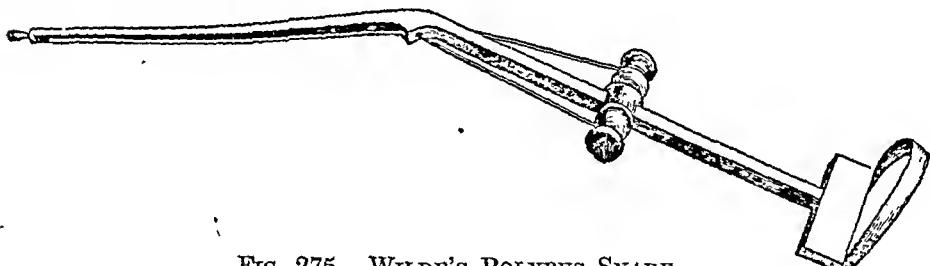
FIG. 275.—WILDE'S POLYPUS SNARE.

The avulsion of a polypus in the meatus is accomplished with Wilde's snare (Fig. 275), the wire loop of which is pushed over the polypus until it reaches a point near the root of the growth, and tightened only as much as is necessary to catch the polypus securely. A moderate pull generally suffices to remove the growth completely. In cases of soft polypi, however, avulsion by means of the snare is seldom complete, as the soft tissue is easily cut through by the wire, and part of the growth remains behind.

Fibrous polypi, which are so firmly connected with the osseous wall that avulsion is impossible even with strong traction, are best constricted with Wilde's snare. The manner of procedure is as follows: The instrument, after its loop has been tightened about the polypi, is twisted on its long axis until a resistance is felt; the wire is then cut off with a pair of scissors close to the crossbar, and the instrument removed from the ear. By means of the twisted wire loop which is left in the ear, the blood-supply to the polypus is cut off; this causes rapid mortification, and the growth is cast off within a few days. In a few cases the root was

discharged with the peripheral, constricted portion of the polypus (Fig. 276). If the constricted polypus does not fall out at the end of a few days, we may try to extract it by catching hold of the ends of the ligature with a pair of dressing forceps; if, however, the obstacle still proves too great, we must increase the torsion by twisting the wire and allow it to remain a few days longer.

Great care must be used in doing avulsion, as the polypus may be firmly united with the tegmen tympani. If we use too much traction the bone may come away with the growth, thus causing an exposure and even injury to the dura. Such an unpleasant occurrence may bring about a secondary basilar meningitis with fatal termination. It is, therefore, always advisable to be as gentle as possible in the extraction of aural polypi, and to take away a little at a time.
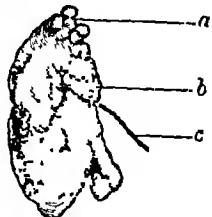
FIG. 276.

a, Root; b, Place of constriction; c, Wire ligature.

(b) **Removal with Instruments.**—In the case of large polypi, the roots of which are so deep that, with the use of the probe, we cannot ascertain with certainty whether the growths arise from the external meatus, the membrana tympani, or the tympanic cavity, avulsion, owing to the danger of tearing out one of the ossicles, the cochlea, or the tegmen, should always be avoided, and excision of the polypi should be undertaken instead.

For this purpose Blake's polypus snare (Fig. 277), which consists of a movable metal cannula, into which the wire loop can be completely drawn, or the snare devised by Ruttin (Fig. 278) may be used. The advantage of this instrument is that it can be made large or small in the meatus to any desired size, whereby it is possible, when there are large polypi filling the meatus, to push it through the narrowest part of the canal, and again enlarge it in the deeper, wider portions of the meatus, and to grasp the growth at its root. An annealed steel wire, 0·1 mm. in thickness, or a thin platinum wire, is the best; A. H. Buck recommends malleable steel wire, No. 37. The oval loop should be preferred to the round. In cases in which the polypi grow from the posterior superior wall of the meatus, or from the tympanic cavity, the loop, as it is being introduced, must always be curved somewhat downwards, so that the anterior portion of the loop may glide inwards along the anterior inferior wall of the meatus, and the posterior portion along the superior wall. In order to pass the loop more easily over the growth, it is advisable not to push the instrument directly forwards, but to advance it with a gentle rotatory movement.

If the snare has been introduced until it is in the neighbourhood of the membrana tympani, the polypus is cut off by gradually tightening the snare, and removed from the ear either along with the instrument or by syringing. The hæmorrhage, which is usually slight, is soon stopped by injections of cold water

or by the instillations of peroxide or adrenalin solution. Severe hæmorrhage is arrested by inserting cotton or gauze tampons firmly into the meatus.
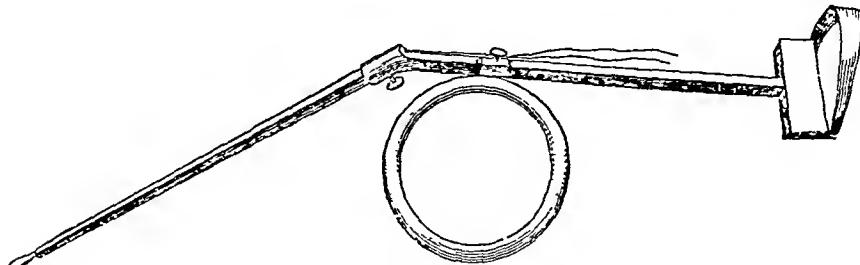
FIG. 277.—BLAKE'S POLYPUS SNARE.

Only after the removal of the bulk of the polypus is it possible to ascertain the seat of the root and to find out whether there are other polypi in the deeper parts of the ear.

If the perforation is small and the membrane bulged out by the
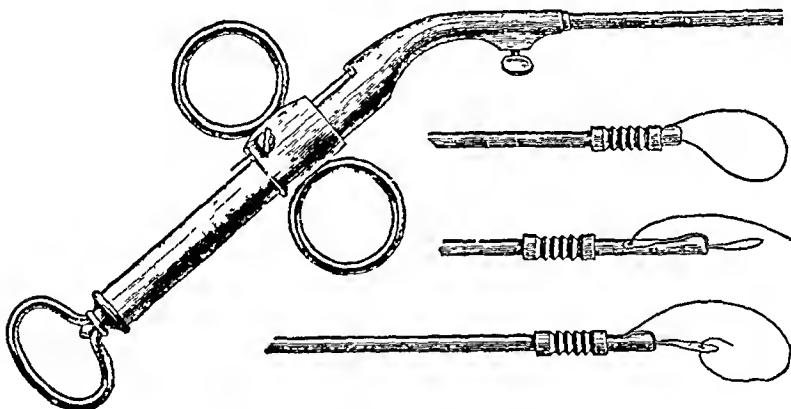
FIG. 278.—RUTTIN'S POLYPUS SNARE.

polypi, the former must be widened by an incision, so that the instrument can be introduced into the tympanic cavity. The most favourable results are obtained in cases in which the growths spring from the internal wall of the tympanic cavity. On various

FIG. 279.—POLITZER'S RING KNIFE.

occasions when small polypi in the attic were recognized with a small tympanic mirror, the author was able to remove them with a small curette bent at right angles to the handle.

Small, soft polypi and granulations in the external auditory

canal, or on the posterior and inferior walls of the tympanic cavity, are best removed with the author's ring-knife (Fig. 279). The removal of the growths with this instrument is more complete than with the wire snare.

The ring-knife, which is inserted into a handle (p. 287, Fig. 131), can be turned in any direction. It is 7 cm. long, and has on its anterior end a concavo-convex ring, the inner margin of which is very sharp. The diameter of the ring varies from 3–3½ mm. to 1½–2 mm. When the growths are on the inferior and posterior walls of the tympanic cavity, the author uses instruments in which the ring is bent at different angles to the long axis of the instrument.

In the case of small, round polypi and granulations in the auditory canal, the instrument is pushed forwards to the growths and its convex surface pressed against them until a firm base is felt. The instrument is then quickly withdrawn, whereby the growths are cut from their bases, and, while they are still adherent to the concave surface of the ring, removed from the meatus. The parts are anæsthetized with powdered cocaine, which is applied by means of the moistened end of a probe.

This procedure is suitable also for the removal of larger growths with thin pedicles. The knife is pushed to the place where the polypi arise, and the ring is pressed against the roots, which are cut through by the quick withdrawal of the instrument.

If the polypoid growths are on the superior portion of the tympanic membrane, they will sometimes be found to completely embed the handle of the malleus; if there is a large defect in the membrana tympani and the malleus is found to be in a carious condition, it should also be removed.

Polypi with thin pedicles are often detached and washed out of the ear by forcible syringing. According to Löwe, attempts should first be made to remove the growths by this procedure before resorting to any operative measures.

(c) **Macerating or Crushing.**—Macerating or crushing is indicated when large portions of the growth, which cannot be caught by the snare or removed with the ring-knife or sharp curette, remain on the membrana tympani and inner tympanic wall, and which are nevertheless so large that their removal by caustics or by the galvano-cautery would take too long.

For this purpose we may use a small pair of dressing forceps, introduced into practice by the author. This instrument has a knee-shaped bend, and is deeply grooved on its inner surface, the anterior end being either quite straight, or (for growths on the inner section of the bulged anterior inferior wall of the meatus, or on the floor of the tympanic cavity) bent at an angle (Fig. 280).

This procedure must be continued until no more of the growth can be caught with the forceps, and only flat remnants remain. For these remnants, as well as for small growths in the meatus, on the remnant of the tympanic membrane, and in the tympanic cavity, Hartmann's forceps (Fig. 281) has proved most serviceable. The soft remnants of the intratympanic polypi

which cannot be seized with the instrument, sometimes shrink after the continued use of alcohol or after the application of strong solutions of silver nitrate and caustics.

(d) Treatment with the Galvano-Cautery.—The remnants of polypi and small granulations can be destroyed with the galvano-
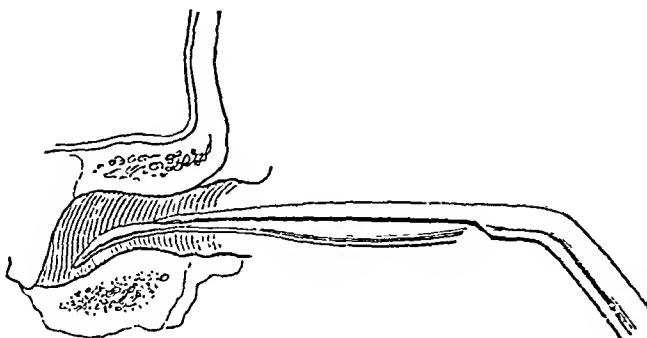
FIG. 280.—POLITZER'S POLYPUS FORCEPS.

cautery when they cannot be removed with the sharp curette or ring-knife. Cauterization should be used only when the growths are situated in the external auditory canal, and on the
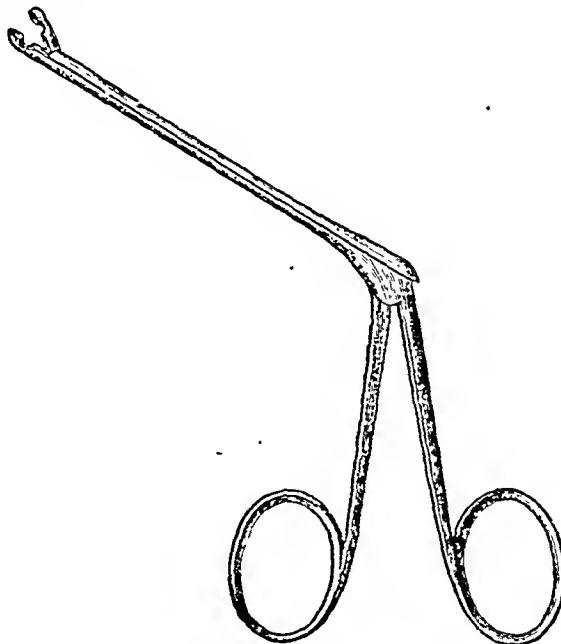
FIG. 281.—HARTMANN'S AURAL FORCEPS.

outer surface of the membrana tympani. Cauterization of the tissue around fenestræ of the labyrinth, or of the portions of the tympanic cavity which are not visible, should be avoided, as this method often sets up a very marked reaction. The great

advantage of the galvano-cautery over the other methods of cauterization is that the growth is, as a rule, more rapidly and more thoroughly destroyed, that it scarcely ever produces a severe inflammatory reaction in the meatus, and that the roots of the growths shrivel up much more quickly. Before using the galvano-cautery, the parts should be thoroughly anæsthetized.

The number of applications of the galvano-cautery varies according to the size and consistency of the growth. Small, soft granulations often disappear after one or two applications. Tough remnants, however, must be repeatedly cauterized before they are completely destroyed. The galvano-cautery snare, after
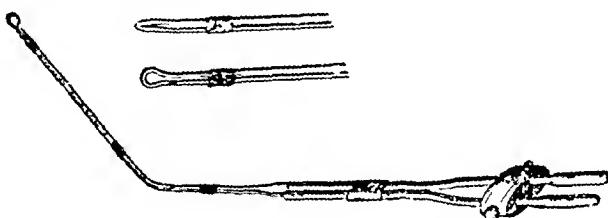
FIG. 282.—GALVANO-CAUTERY POINTS (HALF-SIZE).

the use of which cicatricial strictures of the meatus have been observed, should be used only in exceptional cases—in other words, for fibrous growths or for those which cannot be removed by other means.

For cauterization with the galvano-cautery, delicate cautery-points of various shapes are sufficient in most cases; on the other hand, for growths extending over a large area, flat points, rounded at the end, and capable of being bent in all directions can be used (Fig. 282).

(2) Treatment with Drugs.

(*a*) **The Destruction of Polypi with Caustic Drugs.**—Of all the cauterizing agents, the author has found the perchloride of iron (liquor ferri sesquichlorat.) the most useful. It penetrates much more deeply into the tissue even in cases of hard, fibrous growths, causes mortification and separation of the growths much more quickly, and seldom produces much pain. In every case, before applying this drug, we should thoroughly cocainize the parts. Cauterizing with solid silver nitrate sometimes acts very well, causing the polypi to contract within a short time.

Perchloride of iron is applied by means of a probe, a small brush, or a cotton applicator dipped into the solution. Cauterization is repeated only after the crust has fallen off. In the case of hard growths, the author not infrequently used a crystal of the perchloride of iron. In order to limit its action, and to protect the normal parts of the auditory canal, a small crystal is taken with a pair of forceps, introduced up to the growth, and held there with a plug of

cotton. The perchloride of iron crystal, which rapidly melts, penetrates the tissue and forms a crust without causing any great pain. The crystals are particularly recommended for hard, broad-based growths of the osseous meatus.

(*b*) **Treatment with Alcohol.**—This drug is, in many cases, of excellent value in the treatment of aural polypi and granulations, and is especially suited for:

1. The removal of the remnants of polypi in the auditory canal and on the tympanic membrane.

2. The treatment of intratympanic polypi and the remnants of polypi which have a tendency frequently to recur, and which can seldom be entirely removed by operative means.

3. Multiple granulations in the external auditory canal and on the tympanic membrane.

4. Diffuse, excessive proliferation of the mucous membrane of the middle ear.

5. Cases in which, owing to the mechanical obstruction in the external meatus (exostoses, strictures), the removal of polypi or granulations cannot be effected with instruments.

6. Individuals who dread operations.

The treatment of aural polypi with alcohol is contra-indicated in painful inflammation of the meatus, in caries of the middle ear, and in cases in which, after its instillation, there is severe pain, headache, dizziness, or nausea.

Before using alcohol, the ear must be carefully cleansed and dried with a plug of cotton. After this, the alcohol is warmed and poured into the meatus, where it is allowed to remain for five to ten minutes. If pure alcohol cannot be borne, it is better to begin with a solution containing $\frac{2}{3}$ to $\frac{1}{2}$ water, and to gradually increase its strength. The instillations should be repeated several times a day, and continued until the polypus has completely disappeared by reason of its shrinking. The duration of treatment varies from two to six weeks and over (*vide* p. 430).

By this treatment, not only the remnants of polypi and the granulations will be made to shrivel up, but large fibrous polypi filling the external meatus will also be made to disappear completely. The effect of alcohol on the size of the polypus is often made manifest only after its use for several weeks. From the time when a diminution in its size is noticeable, the process of shrinking goes on very rapidly.

The treatment with alcohol is successful only when it is used daily for weeks and months. As the alcohol treatment is of long duration, one should, in all cases in which it is possible, remove the greater part of the polypus by operation in order to shorten the time of treatment, and then begin the use of the alcohol so as to shrink the roots of the polypus which have been left behind, and which cannot be reached with instruments. The author has never seen unpleasant results follow the use of alcohol.

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Among the rare growths in the sound-conducting apparatus must be mentioned the enchondroma originating in the cartilage of the meatus (Launay, *Gaz. des Hôp.*, 1861), and the thorn-shaped chondroma on the anterior wall of the osseous meatus (Fig. 283). Other rare growths which are also met with are: the chondroma of Gomperz, the chondromyxomata of the cartilage of the ear (Haug), and the osteomata of the mastoid process. Movable osteomata in the meatus and on the mastoid process have been described by Eulenstein and Urbantschitsch. Cylindromata or myxomata cartilagineum of the auricle must also be mentioned, as well as adenomata of the sebaceous glands in the external meatus, lipomata on the auricle and in the meatus, pedunculated papillomata on the upper wall of the meatus covered with normal integument, a papilloma covered with hair on the superior wall of the left meatus, and a melanotic nævus of the skin. The author observed a case of psammoma of the dura mater the size of a hazel-nut; the growth was seated above the tegmen tympani, penetrated into the middle portion of the tympanic cavity, and bent the tendon of the tensor tympani strongly downwards; the occurrence of such a growth is very rare. A highly exceptional condition is the formation of varices on the tympanic membrane, as described by Rohrer

FIG. 283.—THORN-SHAPED CHONDROMA IN THE OSSEOUS MEATUS OF A MAN AGED 22.

(*Vers. deutsch. Naturf. u. Aerzte in München*, 1899), and an intra-tympanic growth observed by Jansen, the construction of which showed great similarity to the thyroid gland (*Ber. d. deutsch. otolog. Gesellsch. in Würzburg*, 1898).

There are still to be mentioned the sarcomata, known as atypical connective-tissue tumours, which, in the majority of cases, present the same malignant characters as the carcinomata, and which occur, as a rule, only in young individuals. Roudot (*Gaz. méd. de Paris*, 1875) observed a sarcoma the size of a walnut, which involved the lobe and tragus; the growth was of twenty years' duration, and was removed by total extirpation. Hartmann (*Z. f. O.*, vol. viii.) describes an interesting case of round-celled sarcoma of the middle ear in a boy three and a half years of age; the growth developed during the course of an acute suppuration of the middle ear, and caused death after five months' duration. Orne Green (*Arch. of Otolog.*, vol. viii.) reported a case of round-celled sarcoma growing from the carious wall of the osseous meatus, and Haug (*A. f. O.*, vol. xxx.) a case of myxosarcoma of the tympanic cavity and mastoid process of a girl eighteen years of age. An angiosarcoma with caries of the walls of the meatus has been described by Milligan, a fibrosarcoma at the pharyngeal orifice of the tube by Haug, a fibrosarcoma with giant cells by Castex, and a lymphangiosarcoma in the meatus by Cohen Servaert (*A. f. O.*, vol. xliii.). Lannois (*Revue hebd. de laryng. et otolog.*, 1898) describes a case of adenocarcinoma originating in the sebaceous glands of the auricle, and Nadoleczny (*A.f.O.*, vol. xlvii.) an endothelioma of the auricle. Stacke and Kretschmann (*A. f. O.*, vol. xii.) have observed a spindle-celled sarcoma in the meatus which resembled a polypus; Robertson (*Transactions of the American Otological Society*, 1870) reported a similar case.

Of mixed sarcomata, the osteosarcoma must be mentioned, which was observed in four cases by Wilde (*loc. cit.*), Wishart and Böke (*W. med. Halle*, 1863), and which, according to these authors, originated in the middle ear.

Attention must still be called to a few pathological growths in the sound-conducting apparatus which do not strictly belong to new formations. As such must be mentioned the so called 'retention tumours': the milium in the external auditory canal, the atheroma of the lobe, and the endothelioma and cysts of the auricle. The last of these, seated on the posterior surface of the auricle, may attain an enormous size. In a case observed by the author the

tumour was twice the size of the auricle; after it was opened, a yellowish fluid, mixed with a sandy mass, was discharged. After partial excision of the sac and the cutaneous covering, cicatrization was brought about by repeated cauterization of the wound with a solution of silver nitrate. Hessler (*A. f. O.*, vol. xxiii.) observed the formation of cysts on the auricle after othæmatomata of traumatic origin.

Before leaving this subject, we must mention partial or complete ossification of the auricle, as described by Gudden, Bochdalek, and Schwabach (*Deutsche med. Wochenschr.*, 1885); ossification of the walls of the cartilaginous meatus; calcification and the deposition of urates in the cartilage of the ear of gouty patients (Garrod); and syphilitic gummatous tumours on the mastoid process. According to Wasmund, the exact amount of ossification of the auricle may be ascertained by the Roentgen rays.

II. Epithelial New Formations.

Epithelial new formations develop most frequently on the auricle and in the external auditory canal, less frequently in the tympanic cavity and mastoid process. The epithelioma is usually developed in the skin on the upper part of the helix, and spreads from here—at first gradually, and then very rapidly—over the greater part of the auricle, the cartilage of which becomes ulcerated and perforated in several places.

If an epithelioma of the auricle is not excised at the proper time, it extends to the side of the head and neck, to the external auditory canal, from here to the middle ear, until, finally, the rest of the bones of the head and the cranial cavity become involved in the process. This destruction may reach such a degree that not only the middle ear, but also the deeper parts of the skull, become involved, causing a fatal termination.

Treatment.—The treatment of epithelioma of the auricle depends on the extent of the growth. If the neoplasm is confined to a circumscribed part of the cutis, destruction of the new growth with the galvano-cautery or lunar caustic, or by curetting it with the sharp spoon, and subsequently applying fuming nitric acid, is often sufficient to bring about a cure. In cases in which the ulcerative process is very extensive, partial or complete amputation of the auricle is indicated. This operation should always be determined upon before the growth has reached the external auditory orifice, for if performed later, it will not be attended with success, owing to the invasion of the cancer cells into the neighbouring parts and into the lymph-glands. Defects of the auricle produced by amputation may be replaced by an artificial auricle or by plastic surgery.

An epithelioma of the external auditory canal develops with symptoms of moist eczema, or with the formation of circumscribed crusts, which are frequently scratched off owing to the great itching; this finally leads to the formation of an ulcerated surface, which spreads outwards towards the auricle, and inwards towards the tympanic membrane. Sometimes the appearance of the growth is preceded by great pulsating pains and a circumscribed loosening of the wall of the meatus, where, after some weeks, an ulcerated, red-spotted, secreting surface with jagged edges is formed. Beside the spongy growths depressed places are seen, in which the white cartilage of the ear and the wall of the osseous meatus are exposed. Epithelioma of the meatus usually ends in death after long-continued pain, facial paralysis, and ulcerating infiltration of the external region of the ear. The fatal result is generally caused by extension of the growth to the middle ear and labyrinth, and from here to the cranial cavity, giving rise to cerebral symptoms. Manasse observed a case of cylindric-celled cancer of the external auditory canal which originated from the ceruminous glands; after extirpation of the growth, cicatrization took place (*A. f. O.*, vol. xli.). Haug saw an endothelial cancer of the external

meatus and middle ear, which broke into the cranial cavity, and which was associated with paralysis of the recurrent laryngeal and hypoglossal nerves (*A. f. O.*, vol. xlvii.).

Epitheliomata in the middle ear and mastoid process arise, according to the observations of Toynbee, Wilde, Schwartze, Lucae, Kipp, Brühl, and others, either during the course of an existing suppuration of the middle ear, or after the cessation of a carious process in the temporal bone. For this reason, the growths protruding through the perforation in the tympanic membrane are at first mistaken for granulations or polypi, till their rapid recurrence after repeated removal and their appearance under the microscope reveal their malignant nature. The course is characterized by intense pain, facial paralysis, profuse hæmorrhages, and infiltration of the lateral cervical glands. A fatal result is usually caused by meningitis, abscess of the brain, sinus-thrombosis,* or metastases in other parts of the body.

At times malignant growths from the neighbouring organs extend to the temporal bone. In Knapp's case (*Z. f. O.*, vol. xi.) a chondrosarcoma of the parotid gland extended to the cavum tympani and cranial cavity; in Pomeroy's case (*Amer. Journ. of Otol.*, vol. iii.) an intracranial myxosarcoma which originated in the middle and posterior cranial fossæ ended fatally with brain symptoms; in Bonnafont's case (*loc. cit.*) a carcinoma of the parotid gland extended to the ear.

The extension of cancer of the tongue and of the superior maxillary bone to the Eustachian tube has been observed by the author. In these cases there were symptoms of otalgia and closure of the tube on the affected side. In one case there was a serous accumulation in the tympanic cavity. The tone of a vibrating tuning-fork placed on the vertex was always perceived better on the affected side. The *post-mortem* examination showed that the growth had extended to the basilar fibro-cartilage, and to the connective tissue surrounding the cartilaginous portion of the Eustachian tube. The entire tube appeared embedded and compressed in a fatty, infiltrated mass which surrounded it. In microscopic sections, the epithelial new formation was seen in the form of cones and nests, or in some specimens, as cancroid corpuscles reaching close to the cartilage of the tube. The cartilage of the tube itself was not affected at any part by the cancerous mass. On the other hand, in the membranous portion of the tube, scattered cancer-nests were found, which did not, however, reach to the epithelium. Manasso (*Deutscher Otologentag*, 1904) described a primary endothelioma of the middle ear—that is, of the petrous bone.

NEUROSES OF THE SOUND-CONDUCT-ING APPARATUS.

1. Otalgia.

Otalgia is caused by an affection of the sensory nerves supplying the organ of hearing. It occurs either as a localized ear disease or as part of a trigeminal or cervico-occipital neuralgia. Not infrequently the pain in the ear radiates from the teeth, from the maxillary joint (Kretschmann)† or from the larynx (Rohrer).‡ It occurs more frequently in females and is often of a hysterical nature.

Neuralgia of the auricle is usually limited to a circumscribed

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* Cp. Kretschmann, *A. f. O.*, vol. xxiv.; and Zeroni, *A. f. O.*, vol. xlviii.
† *Archiv f. Ohrenheilk.*, vol. lvi.
‡ *Schweizerische Zeitschrift f. Zahnheilk.*, vol. x.

part. On the anterior surface it is due to an affection of the trigeminus (auriculo-temporal nerve), on the posterior surface to an affection of the ascending branches of the superficial branches of the cervical plexus (auricularis magnus and occipitalis minor nerves). Besides the painful point on the auricle, another point of tenderness is often found on the mastoid process (Valleix's mastoid point). By slight touch or pressure, the pain is increased; by great compression, however, it is sometimes diminished. A transitory congestion and swelling of the affected parts sometimes occur during an attack.

Otalgia of the external auditory canal can be diagnosed only when the pain is localized in the cartilaginous section; when the pain is localized in the osseous portion, it is impossible to distinguish between an otalgia of the auditory canal and an otalgia of the middle ear.

Neuralgia of the tympanic plexus, which is made up of branches of the trigeminus, sympathetic, and glosso-pharyngeal nerves, occurs either as a local neurosis or as part of a neuralgia of the third cranial nerve, more rarely of the second branch of the fifth. In the latter case the otalgia is confined to the middle ear, while if the third branch of the fifth nerve is affected neuralgia pains are experienced in both the external and middle ears. The mastoid process is rarely the seat of a persistent pain, and when such is really the case, it occurs in adhesive processes and in suppurations of the middle ear. The author has repeatedly observed a continuous neuralgia due to a firm cicatrix after mastoid operations.

Etiology.—The causes of otalgia are: Cold, anæmia, hysteria, neurasthenia, sexual derangements, perineuritis and pressure on the nerve trunks, exostoses in the interior of the cranium, hyperæmia, inflammation of and new growths in the Gasserian ganglion, tumours of the brain,[*] caries of the cranial bones and cervical vertebræ, and the action of severe noises. The author has frequently observed a persistent otalgia in carcinomata of the superior maxilla, and in the retropharyngeal region; it is described as an early symptom of cancer of the tongue by Richard and Körner. One of the most frequent causes of otalgia in children is carious teeth, as well as ulcers in the larynx and in the neighbourhood of the pharyngeal orifices of the Eustachian tubes. When associated with herpes zoster of the face it is part of a trigeminal neuralgia.

The attacks are usually intermittent, and are characterized by severe tearing and boring pains in the interior of the ear, which last several hours, and generally return at irregular intervals. The course of otalgia is often typical.

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[*] Krepuska (*Gesell. der ungar. Kehlkopf- und Ohrenärzte,* 1897) reports a case in which a sarcoma of the Gasserian ganglion caused a severe otalgia which could not be alleviated. In a child observed by Spira, an otalgia was the only initial symptom of a severe diphtheria (*Przeglad lekarski* 1899).

The occurrence of a form, called by the older authors intermittent otalgia, has been confirmed by Voltolini, Weber-Liel, and Orne Green.* The author observed that intermittent otalgia occurred usually in the spring, and in individuals who lived near marshy, damp districts. Intermittent otalgia may be attributed to malarial infection (intermittens larvata) only when other symptoms point to such a condition, as an enlarged spleen, etc.†

Kaufmann (*Wien. med. Blätter*, 1896) describes a form of otalgia which accompanies influenza; the affection is made evident by severe pain in the ear, which begins with fever and general symptoms (headache, pains in the joints, depression) and lasts several days. The condition of the tympanic membrane during these attacks is normal.

During an attack of otalgia, subjective sensations of hearing and deafness, as well as hyperæsthesia acustica, sometimes occur, and there is not infrequently a hyperæmia and hyperæsthesia of the auricle and temple, which disappears after the attack. Loud noises near the patient increase the pain.

Course.—Otalgia runs an acute or chronic course. In the former case the neurosis lasts for a few days or weeks, and appears in irregular, rarely regular, intervals. The course of chronic otalgia is uncertain; the attacks often occur at intervals of weeks or months, and may last for years. Cases of chronic otalgia having a typical course are seldom observed. In one of the author's cases, the attacks occurred regularly on the left side for ten years. These came on every month, or every second month, and ended, after several hours' duration, in a sound sleep. Radiating otalgia, or that combined with neuralgia of the trigeminus, depends on the course of the original disease.

The differential diagnosis between otalgia and pain due to an inflammatory condition, is made by the absence of inflammatory phenomena in the ear. If a case is really one of otalgia, it must be determined whether it is a local neurosis or part of a trigeminal or cervico-occipital neuralgia, or whether it is a pain radiating towards the ear. The teeth must, therefore, be carefully examined in every case; if they are diseased, it may be assumed that they are the probable cause of the otalgia. If symptoms of a pharyngeal or laryngeal affection are present, we must ascertain by careful examination whether the pain in the ear is not due to these conditions.

The connection of otalgia with neuralgia of the fifth cranial nerve and cervical plexus may be ascertained by examination of the known painful points (*points douloureux*). In trigeminal neuralgia, either all or only a few spots are painful on pressure. In such cases the otalgia is frequently so marked that it is only by ascertaining the painful points that the existence of an extensive neurosis of the trigeminus is discovered.

* *Neuralgia in and about the Ear* (*Transactions of the American Otol. Soc.*, vii., 1875).

† Coste, *Contribution à l'étude clinique des otites et des otalgies palustres* (*Arch. de méd. et pharm. mil.*, 1906).

Prognosis.—The prognosis of otalgia is, in the acute typical cases generally favourable, even if the affection is part of a trigeminal neuralgia. The prognosis is also favourable if the affection is due to a carious tooth. It is, on the other hand, unfavourable in cases of protracted neuralgia of the fifth cranial nerve, especially if it is due to a cerebral affection, or to an irremediable compression of the affected nerve-trunk. Other unfavourable conditions are: anæmia, marasmus, long-lasting syphilis, tubercular ulcers in the larynx, and a carcinoma in the region of the Eustachian tube.

Treatment.—The treatment of otalgia depends on the cause and duration of the disease. If dental caries is the cause of the affection, the patient should have his teeth attended to. In cases of acute otalgia, localized or associated with neuralgia of the fifth cranial nerve—whether the attacks occur irregularly or periodically—quinine or any of the antineuralgic medicaments, such as phenalgin, antipyrin, etc., may be given. In the typical form, quinine (0·25–0·5 gramme at a time) administered two or three times in the course of two or three hours before the attack sometimes has a beneficial effect. The action of quinine is often increased by the addition of iodide of potassium (1 of quinine to 2 of potassium iodide).

When the affection is associated with syphilis, salvarsan injections must be given in addition to large doses of potassium iodide. During severe attacks it may be necessary to administer morphine internally or by subcutaneous injection.

In the chronic forms treatment seldom produces any striking results; sometimes, however, by the use of one or the other remedy, the attacks become milder and less frequent. The internal remedies which are most commonly employed are quinine iodide of potassium, iodide of sodium, iodipin 2–3 grammes daily (Nobel, Pins), arsenic (Fowler's solution), bromide of soda 1·0–2·0 grammes a day, the more recent liquor arsen. (Pearson), salicylate of soda, iron, oil of turpentine (5–10 drops in capsules), atropine (0·0005–0·002 gramme a day), pyramidon 0·3–0·5, citrophen 0·5, antipyrin 0·5 a day, cephaldol 0·5–1·0, aspirin 0·5–1·0, indoform 0·5–1·0 pro dosi, anæsthesin 0·25–0·5 pro dosi, and oxide of zinc, the last mentioned either alone or in the form of Meglin's pills (zinc. oxid., rad. valerian., āā 10·0, ext. hyoscyam. nigr. 1·0, ft. 100 pills; the dose to be gradually increased from 1 to 30 pills and then gradually diminished).

Of the external remedies, vesicants to the mastoid process have sometimes proved effectual, as have also the endermic inunctions of morphine or veratrine ointment, and narcotic plasters. In the obstinate acute, as well as in the chronic forms, galvanization may be tried, as it very often causes a considerable improvement when all other means fail. According to Erb, when applying the galvanic current the anode pole should be placed

on the ear and the cathode pole on the neck. The faradic current, owing to the frequent coexistent hyperæsthesia of the skin, is, as a rule, not recommended.

In cases in which the pain affects the entire region of the ear, and is increased upon pressure between the ramus of the jaw and the mastoid process (corresponding to the course of the cartilaginous portion of the Eustachian tube), a considerable improvement sometimes takes place after repeated massage; by this procedure a complete disappearance of the otalgia has even been known to occur within several days. If, after a suppuration of the middle ear has run its course, a neuralgia of the mastoid process occurs which cannot be alleviated, and if the cause is due to an excessive growth of connective tissue, the chiselling away of a piece of bone from the mastoid process is indicated. If neuralgia of the mastoid process exists after a healed radical operation, the same procedure is indicated. In a girl eighteen years of age, in whom, after a successful mastoid operation, a neuralgia of the cicatrix, associated with melancholia, had existed for one year, the author obtained complete cure after chiselling away a sclerosed portion of bone from the mastoid process.

Sometimes, in hemicrania, a dull pain arises in the ear and in its neighbourhood, which is accompanied by hyperæmia and a feeling of warmth and burning on the auricle and temple. Eulenburg and Möllendorf call this form *hemicrania angio sive neuroparalytica*, and trace it to an affection of the sympathetic nerve.

Cutaneous hyperæsthesia and anæsthesia of the auricle and external meatus, although occurring but rarely, also belong to the neuroses. Hyperæsthesia of the auricle is often the sequela of frost-bites, inflammation, and eczema. Many persons are especially sensitive to the effect of cold draughts or winds, and find it necessary to continuously wear a pledget of cotton in the ear as a source of protection. Narcotic applications do not diminish the sensitiveness. On the other hand, methodical applications of cold to the external region of the ear, smearing the parts with fat, and the application of electricity, sometimes have a good effect. That itching of the skin (pruritus) due to a neurotic origin may also occur has already been mentioned in the Anomalies of Secretion in the External Auditory Meatus (*vide* p. 199). The affection is often very irritating, and leads, from the intense itching, to excoriations and inflammations. Painting with liquid vaseline, with a mixture of epicarine and alcohol (1·0–20·0 or 30·0), with an ointment of epicarine (1·0–20·0, to which 1·0 anæsthesin is added), with a concentrated solution of picric acid, or with a mixture of p-naphthol 0·2, alcohol and sulphuric ether āā 10·0, often lessens the itching for a long time.

Anæsthesia of the ear most often affects the auricle, especially its anterior surface, which is supplied by the branches of the fifth cranial nerve. It seldom occurs as an independent affec-

tion, but is more often a part of a diminished sensibility of the corresponding half of the head, especially met with in hysteria, cerebral diseases, brain tumours, after cerebro-spinal meningitis, and after the effect of a severe noise.

Anæsthesia of the external meatus is a disease of which little is known (see Hysteria). On the other hand, as the author has already mentioned (*Wien. med. Woch.*, 1863), a decrease in the sensibility of the mucous membrane of the middle ear, especially in chronic adhesive processes, is by no means uncommon. In the hyperæsthesia of hysterical patients, it has been repeatedly observed in combination with anæsthesia of the tympanic membrane.

2. Motor Neuroses.

Under motor neuroses we must consider the following:

1. Spastic Contractions of the Muscles of the Auricle, which most frequently appear as part of the spasm of the facial muscles (*tic convulsif*), less often as an independent neurosis.

2. Spastic Contractions of the Intratympanic Muscles.— The observations hitherto recorded apply to spastic contractions of the tensor tympani, and must not be confounded with voluntary contractions of this muscle (*vide* p. 63). They may be recognized either by a distinctly visible movement of the membrana tympani or by the fluctuations of the fluid in a manometer hermetically inserted into the meatus (*vide* p. 59); in the latter case, at every contraction of the muscle, a negative oscillation of the fluid will be seen. The contractions are manifested subjectively as well as objectively by a loud cracking sound, or by a dull throbbing in the ear. In one case, the hearing tests showed that during the contractions the hearing distance was diminished, that deep tones became deadened and indistinct, and that high tones ascended about one-quarter of a tone.

From the fact that during strong contractions of the orbicularis palpebrarum muscle contractions of the stapedius muscle are set up (p. 63, Lucae), Gottstein believes (*A. f. O.*, vol. xvi.) that, in a case of blepharospasm observed by him in which during the attack the patient complained of a rushing noise in the ears, the latter was caused by a clonic spasm of the stapedius.[*] Habermann observed (*Prager med. Wochenschrift*, 1884) a case of clonic spasm of the stapedius muscle in which there were subjective noises, dizziness, and a feeling of tightness in the head; after tenotomy of this muscle, these symptoms disappeared. A case of deafness and tinnitus, which was associated with paresis of the stapedius nerve (as part of a facial paralysis caused by a fracture of the base of the skull), was cured by Matte (*Deutsche med. Wochenschr.*, 1890) by tenotomy of the tensor tympani muscle.

3. Clonic Spasms of the Muscles of the Eustachian Tube. —This has been independently observed by Schwartze, Brunner, Todd, Boeck, and the author. Boeck in one case described

[*] Ostino and Calamina, *Archivio ital. di otologia*, etc.. 1900.

a crackling sound which occurred synchronously with the pulse; in the cases observed by the author the crackling sound was caused by the contractions of the muscles of the tube, and resembled the irregular ticking of a watch held at some distance from the ear; the sound continued during sleep, and could not be voluntarily suppressed by the patient. With every crackling sound there was a corresponding contraction of the soft palate. The noise stopped when the soft palate was raised with the finger. Rüdiger observed on himself, autophony during contraction of the muscles of the tube. In a case of Schwartze's, the affection was combined with spasm of the muscles of the larynx, eyes, mouth, and nose. Galvanization of the soft palate, and massage of the region between the ramus of the inferior maxilla and the mastoid process, have proved the best therapeutic measures.

INJURIES OF THE SOUND-CONDUCTING APPARATUS.

Lesions of the auricle are classified according to the nature of the violence—that is, whether they are produced by stabs, blows, cuts, tears, or contusions. Their importance depends on the severity of the wound and on the extent of the injury. Superficial bruises confined to the skin always heal without any visible consequences, while deep lesions affecting the perichondrium or the cartilage, such as othæmatomata, always produce a deformity of the auricle. The course of incised wounds of the cartilage of the ear, so frequently met with in fights, duels, etc., is most favourable, inasmuch as, even when the auricle is cut through to a large extent, healing by first intention occurs in most cases after the edges of the incision have been sutured together. The termination of tears, bruises, and bites is less favourable. In all these injuries, after the torn cutis has sloughed away, and the cartilage has been exposed, ulcers occur, the cicatrization of which is generally associated with shrinking and deformity of the auricle. In wounds due to cuts, which extend to the external auditory orifice, the edges of the wound must be carefully sutured in order to avoid cicatricial contraction and stenosis.

Injuries of the external meatus more frequently affect the osseous than the cartilaginous portion. Lesions of the cartilaginous meatus are confined either to this part, or are combined with injuries of the auricle. The lining membrane of the cartilaginous meatus, seldom the cartilage itself, is most frequently injured by awkward attempts at extraction of foreign bodies; from such lesions, however, deep-seated changes never remain.

Injuries of the osseous meatus are caused by direct or indirect violence. Direct injuries affect either the lining membrane of

the meatus alone or the osseous wall as well. In these cases violent attempts at extraction of foreign bodies must also be looked upon as the chief cause of injuries of the osseous meatus. The second most frequent cause is the introduction of hard bodies into the meatus to relieve a marked pruritus; by an accidental push they are forcibly driven against the wall of the meatus.

Fractures of the walls of the meatus from direct violence are more frequent; they are due to fractures of the skull caused by blows, kicks, or falls, which extend to the walls of the meatus, or to injuries caused by violent blows on the lower jaw. In such cases the condyloid process of the inferior maxillary bone is driven with great force against the wall of the meatus.*

The site of the lesion depends on the place at which the injury is inflicted. Violence applied to the top of the head usually causes a fissure of the superior wall of the meatus; to the back of the head, a fissure of the posterior wall of the meatus; and a blow on the jaw, an injury to the anterior wall. On the anterior wall, fissures not only arise by indirect violence, but also by comminuted fractures; in such cases it is by no means infrequent to see broken-off pieces of bone discharged with the pus or extracted from the meatus. Burnett (*Amer. Journ. of Otol.*, vol. ii.) observed caries and necrosis of the injured anterior wall of the meatus after violence applied to the inferior maxillary bone. According to the observations of Kirchner† and the author, inflammations of the lining membrane of the meatus and middle ear may arise from violence applied to the inferior maxillary bone without fracture of the osseous walls of the meatus.

The terminations of fractures of the meatus are either recovery without subsequent deformity, or caries and necrosis of the affected wall with exfoliation of sequestra and stenosis of the meatus. Fissures on the posterior wall may lead to traumatic inflammation of the mastoid cells, and may cause death by producing a thrombosis of the sigmoid sinus. In like manner fissures of the superior wall of the meatus, with a simultaneous injury to the dura mater, may terminate fatally by setting up a meningitis. Fractures of the anterior wall, after a previous suppuration, heal by the formation of osteophytes.

As a rule, fractures are not confined to the meatus, but are usually complicated with fissures of the superior and inner walls of the tympanic cavity, of the mastoid process, of the petrous portion of the temporal bone, and of the base of the skull. In the majority of cases the trauma is associated with rupture of the tympanic membrane, and is accompanied by profuse

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* According to Hasslauer (*Z. f. O.*, 1899), in thirty-three cases of fracture of the walls of the meatus, fifteen were due to direct violence on the chin or on the rami of the inferior maxillary bone.

† Kirchner (*Würzb. med. Abh.*, 1901) observed neuralgia in the parts supplied by the auriculo-temporal nerve after injuries of the meatus.

hæmorrhage. In cases in which the chorda tympani nerve is injured by the fissure, disturbances of taste are observed on that half of the tongue. Injuries of the tympanic plexus and of the facial nerve are less frequently met with. If the fissure extends to the capsule of the labyrinth or to the cranial cavity, there may be an abundant discharge of the cerebro-spinal fluid from the ear, which may be associated with more or less severe headache, vertigo, nausea, vomiting, tinnitus, and severe deafness. The fluid flows off through the ruptured tympanic membrane, or through a fissure in the superior wall of the meatus. The quantity of the serous discharge varies, according to the statements of different observers (Toynbee, Hagen, Bruns, Chelius), between 13 and 981 grammes in twenty-four hours.

In concussions of the skull due to a blow or fall, there are brought about, as the operations of Passow, Wagenhäuser, and others show, a hæmato-tympanum and ecchymoses in the external meatus and on the membrana tympani, with a temporary disturbance in hearing; or if there is a simultaneous concussion of the labyrinth, there may be a permanent hardness of hearing or complete deafness. In injuries complicated with fracture of the base of the skull, death is usually caused by the intercurrence of a meningitis. Cure has been rarely observed. In injuries of the pyramid without fracture of the base of the skull, the possibility of recovery is not excluded even in cases which run their course with serious clinical symptoms. In all injuries of the organ of hearing in which one suspects a fracture, one should have X-ray pictures taken in order to ascertain, if possible, the location and extent of the lesion. By this means we are able to locate foreign bodies, such as projectiles, etc., and are in a position to adopt surgical methods for their extraction.

Some rare examples of injuries of the sound-conducting apparatus are: O. Wolf's case of gunshot-wound of the Eustachian tube (*A. f. A. u. O.*, vol. ii.) in which the projectile entered beneath the zygomatic arch, passed through the left superior maxillary bone, and became wedged in the tube. The symptoms of occlusion of the tube were temporarily improved only by repeated paracentesis of the membrane. Bezold (*Berl. klin. Wochenschr.*, 1883) reports the case of a stab of the Eustachian tube in which an atresia of the tube resulted later. This case is of special interest from a forensic point of view, in so far as the patient was suspected of simulation.

In a case observed by the author, the projectile penetrated the parotid gland, the meatus and the mastoid process, and reappeared at the posterior portion of the latter; the sequelæ of the injury were stricture of the middle portion of the meatus, a fistula of the parotid gland which discharged its contents into the meatus, and a facial paralysis. Biehl (*Wien. klin. Wochenschr.*, 1900) saw, after a stab wound of the inferior wall of the meatus, a facial paralysis occur five months later which was associated with hyperhydrosis of the corresponding side of the face. Cassells (*Glagow Med. Journ.*, vol. viii.) saw, in a girl seven years of age, a hæmorrhage from the sigmoid sinus, which resulted from an injury to the mastoid process and ended in recovery. In a woman who was injured by a stab with a dagger, the weapon, which entered

in front of the tragus, penetrated both the anterior and posterior walls of the meatus, and the broken-off point remained fixed in the posterior wall of the meatus. Facial paralysis and a slight hæmorrhage followed. During attempts at extraction of the broken-off point, a profuse hæmorrhage from the sinus occurred. In like manner the author observed (*Monat. für Ohrenheilk.*, 1899), in a Venetian who had a complete facial paralysis after a gunshot-wound, the projectile in the posterior portion of the pyramid. According to Passow,* in cases of gunshot-wounds of the middle ear, it is advisable to extract the projectile as soon as possible, as it may sooner or later bring about an otitis media with its dangerous complications.

Fractures of the handle of the malleus belong to the rarer injuries of the organ of hearing. They are caused by direct violence on the tympanic membrane, by the introduction of hard bodies into the meatus, by severe injuries to the head due to a fall from a great height, and by extraction of foreign bodies: they may heal by the formation of callus, or the parts may remain ununited. In either case the inferior broken end forms an obtuse angle with the superior part (Roosa).† On examination with Siegle's speculum, the inferior un-united end of the fractured handle shows considerable motions, while the superior portion remains fixed.

Injuries of the sound-conducting apparatus are also caused by thermic and chemical agencies. By the entrance of hot fluids into the ear, the walls of the meatus are much less affected than the tympanic membrane; in such cases, after profuse sup-puration of the middle ear, a persistent perforation of the membrane remains. Opitz (*Allg. mil. Ztg.*, 1865) found, among recruits, scars in the meatus due to the introduction of the hot vapours of burning wax and tallow; Weintraub, erosion of the cartilagi-nous meatus owing to cauterization with solid nitrate of silver, which resulted in stricture. Cases of burning, caused by the pouring of molten lead or iron into the auditory canal, have been frequently reported. Such cases generally end in deafness and permanent facial paralysis, or in death from meningitis.

Chemical agents such as nitric and sulphuric acids, a solution of the sesqui-chloride of iron, caustic alkalies, nitrate of silver, chloroform, ether, and strong ammonia cause more or less severe erosions. The lesions produced by these chemical agents are: destruction of the tympanic membrane with exfoliation of the ossicles, caries of the walls of the auditory meatus and tympanic cavity, facial paralysis, polypi, persistent perforations, adhesive processes, and even death in cases in which the trauma is very deep and extensive.

We must also add here lesions of the ear caused by mechanical agents such as changes in air-pressure, as are found in caisson-workers, in divers, and in aeronauts‡ (see p. 175). In caisson-workers, who work in the bed of a river where the air-pressure is raised 1–3 atmospheres, there occurs, even when they are grad-ually lowered, a painful feeling of pressure in the ear, which, if the Eustachian tube is permeable, soon disappears after repeated

* *Die Verletzungen des Gehörorgans*, 1905.
† Szenes, *Sur les lesions traumatiques de l'organe auditif* (*Ann. de malad. de l'oreille*, etc., 1898).
‡ *Pathologie der Luftdruckerkrankungen des Gehörorganes*, Dr. Ferd. Alt, R. Heller, W. Mager, Herm. v. Schrötter (*M. f. O.*, 1897).

acts of swallowing. If, however, the Eustachian tube is not permeable, and the air in the tympanic cavity cannot become equalized, the tympanic membrane sinks inwards, and the membranous wall of the tube is closely approximated to the cartilaginous wall by the over-pressure in the caisson. The consequence of this condition is that the tympanic cavity becomes entirely shut off, and a venous congestion of the vessels of the middle ear occurs, which leads to the exudation of serum and to hæmorrhages into the tympanic cavity. In such patients the drum membrane is found retracted, injected, of a violet or dark purple colour, and covered with ecchymoses; it is rare to find the membrana tympani ruptured, and then only when the membrane is atrophic. The accompanying symptoms of these severe forms are: pressure and severe piercing pains in the ear, which are accompanied by a hæmorrhagic discharge from the ear and nose. When the air-pressure is stationary, no aural disturbances are noticeable.

The majority of aural affections in caisson-workers (*loc. cit.*) occur, according to the investigations of Herm. v. Schrötter, Heller and Mager,* during the stage of decompression, if this is carried out too rapidly. In addition to the lesions already mentioned, gas-emboli are induced during the stage of decompression in consequence of the development of gas in the blood. These gas-emboli may cause permanent disturbances of hearing through ischæmia, and through local destruction of the central fibres of the auditory tract, the auditory nerve and its branches.

Owing to the rise in blood-pressure in the vessels of the middle ear and labyrinth, which is brought about by the rapid decompression, transudations and hæmorrhages take place in these two cavities (Alt, *loc. cit.*). The symptoms of this affection are as follows: The workmen are apparently in good condition when removed from the caisson; several minutes to several hours after they have left the caisson there is a sudden and severe collapse which is associated with dizziness, tinnitus, and vomiting, with or without consciousness, and with a deafness which is seldom of a permanent nature. For some time after such an attack there are disturbances in gait, dizziness, and subjective noises. Individuals with an acute middle-ear suppuration must not be subjected to the high pressure in the caisson; dry perforations are no contra-indication (Heermann).†

Divers and aeronauts are affected with a similar disease. In the former, according to Koch, at a depth of 2–4 m. there is a feeling of pressure and pain in the ear, which suddenly ceases upon cessation of the increased air-pressure. As the diver is pulled up, the pressure, pain, and ringing in the ears disappear as soon as he

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* *Festschrift zur* 100 *jährigen Stiftungsfeier des Friedrich-Wilhelm-Institut,* Berlin, 1895.

† Volkmann's *Vorträge,* New Series, 1902.

is out of the water.   In sponge and pearl fishers, who, according to Catsaras, remain a long time at a depth of 25–30 m. and who are rapidly pulled up, inflammations and hæmorrhages in the organ of hearing are not infrequent, and are accompanied by a group of symptoms similar to that of Menière's disease.

In aeronauts the great changes in air-pressure are much less marked than in caisson-workers and in divers; nevertheless, when at a great height, by the rapid rising and falling of the air-ships or aeroplanes, severe lesions of the organ of hearing may take place just as in the other two occupations.

In reference to lesions of the sound-conducting apparatus from a medico-legal standpoint, no general rules can be laid down, as the injuries are so varied that there are scarcely ever two cases which are entirely alike.   Therefore, in estimating the lesion in a given case, the nature of the violence and the extent of the injury should always be considered, and particular attention should be paid to the consequences of the latter.   It is of great importance that, in order to verify the statements of the injured individual and to make a diagnosis, he must be examined as soon as possible after the injury.

In judging injuries of the auricle, the degree of deformity caused by the injury is mainly to be considered.   Contusions, stabs, sword-cuts, and even extensive disturbances of continuity of the auricle, may heal by first intention, and may be regarded as slight injuries, inasmuch as they do not leave any marked change in the form of the auricle.   On the other hand, all injuries which, in consequence of inflammation, destruction, necrosis, and exfoliation of the cartilage, cause a shrinking, deformity, and loss of the auricle must be regarded as serious owing to the disfiguration.

The estimation of the severity of lesions of the external auditory canal depends on whether the injury is confined to its lining membrane, or whether there is also a fracture of its osseous walls.   In the former case the injury will be called slight owing to the fact that recovery is usually prompt and without any evil sequelæ.   On the other hand, when the bone is fractured, especially when there is a comminuted fracture of the anterior, or a fissure of the posterior wall, the injury must be regarded as serious, because the consecutive inflammation often leads to caries, stricture of the meatus, or to an extensive mastoiditis, whereby the hearing is often permanently impaired.

In estimating the severity of injuries of the tympanic cavity, and of the complicated fissures of the temporal bone in which the pyramid, the walls of the tympanic cavity and of the external auditory canal, and the base of the skull are involved, the time of the examination is of chief importance.   Within the first few days after the occurrence of the injury, a definite opinion as to the nature of the lesion can be given only when the latter is

combined with such serious symptoms of a simultaneous brain lesion that an unfavourable termination may with great probability be foreseen. If, on the one hand, symptoms of immediate danger are not present, a final opinion should be postponed until the termination and result of the lesion can be finally determined. The reason for this is that apparently slight injuries of the temporal bone may lead to permanent disturbances and even to a fatal termination, while severe fractures, accompanied by a profuse hæmorrhage and even by a discharge of cerebrospinal fluid from the ear may recover without any impairment in the aural mechanism. It usually takes a long time for the sequelæ of such injuries—provided that they do not cause a fatal termination—to subside to such an extent, that the process may be said to have run its course. In the majority of such cases, the injury should be considered serious if the patient is incapacitated for a long time, and if a permanent impairment in the hearing remains. Those lesions which cause a salivary fistula in the external auditory canal ·or a paralysis of the facial nerve (Biehl) must also be considered as serious, even if they are not associated with any disturbance of hearing.

The estimation of injuries caused by chemical and thermic agents depends on the changes in the auditory canal and on the tympanic membrane, on the changes brought about by the suppuration in the middle ear (caries and necrosis of the temporal bone), and on the degree of the disturbance of hearing. What has already been said in reference to the estimation of other injuries also applies to lesions of this nature.

Aural Affections and Life Insurance.

The author would also like to add a few remarks on the life insurance of individuals affected with ear diseases. Although this subject has already been thoroughly discussed, there is as yet no firm opinion as to what class of patients with ear diseases should be accepted without endangering the interests of the company, and what class should be rejected. Nor are the opinions as to conditional acceptance—that is, the acceptance of individuals by the company with increased premium in certain forms of ear diseases—at all clear.

Life-insurance companies should not regard the following affections of the ear of importance, in so far as they neither influence the length of the life of the individual, nor predispose towards the development of a serious affection: (1) All malformations of the auricle and external auditory canal, including congenital atresia of the latter. (2) The various forms of inflammation of the auricle, furunculosis of the external meatus which arises from time to time, the slighter forms of otitis externa

diffusa, eczema of the auricle and meatus, and exostoses and strictures of the auditory canal when not associated with a purulent discharge. (3) All affections of the middle ear which run their course without suppuration and without perforation of the tympanic membrane; in such cases the degree of the disturbance of hearing and the simultaneous complication with a labyrinthine affection are of no importance. (4) All disturbances of hearing which, without an aural discharge, can be traced to a local affection in the labyrinth. (5) All middle-ear suppurations which have run their course, and in which the perforation in the drum membrane is closed by a cicatrix, whether the latter is adherent to the inner wall of the tympanic cavity or not.

On the other hand, all persons in whom the aural examination shows that the following affections of the organ of hearing are present should be unconditionally rejected: (1) Ulcerative processes on the auricle and in the external auditory canal, which are due to the breaking down of an epithelioma. (2) Lupus of the external ear, inasmuch as experience has shown that individuals affected with this disease do not live long. (3) Strictures and exostoses of the meatus when associated with a purulent discharge. (4) Chronic, purulent inflammation of the external auditory canal with exposure of its osseous walls. (5) Chronic suppuration of the middle ear with perforation of the drum membrane, irrespective of whether it is uncomplicated, or whether it is associated with the formation of granulations and polypi, with caries in the temporal bone, or with a paralysis of the facial nerve. (6) Cured radical operations, on account of the danger of a recurrence. (7) All affections of the ear associated with dizziness and a disturbance of equilibrium, whether these symptoms arise from an affection of the organ of hearing or from the central nervous system.

A conditional acceptance—that is, with increased premium— may be permitted in individuals who, in consequence of a former suppuration of the middle ear, have a persistent perforation (dry) in the membrane, because in these cases the middle-ear suppuration returns more easily than in cases in which the opening is closed by a cicatrix. The acceptance of cases is rendered more difficult if there is a marked desquamation of epithelium in the meatus and tympanic cavity, if crusts occasionally form in the middle ear, and if a chronic naso-pharyngeal or chronic pulmonary catarrh is simultaneously present.

The following should not be absolutely rejected, but deferred until the affection is completely cured: (1) All acute and chronic cases of eczema and diffuse inflammation of the external auditory canal, which extend deeply into the meatus and cause a stricture. (2) Suppurations of the middle ear, which have lasted but a few weeks or months and do not exclude the possibility of a cure. If the otorrhœa can be cured, a favourable

result will be evident after several weeks' treatment. If the discharge does not cease after proper treatment, the case is to be rejected. Individuals who have been deferred for a time must be re-examined by a specialist, and it must be proved that the aural affection has been cured for at least three months. (3) All syphilitic ear affections, especially when the symptoms of a general syphilis are present (exanthemata, pharyngeal ulcers, glandular swellings). On the other hand, when the deafness has lasted for years, and all symptoms of the general syphilitic affection have disappeared, the person may be accepted by the company without fear.

The Diseases of the Nasal Cavity, the Naso-Pharynx, and the Accessory Sinuses of the Nose with Reference to Diseases of the Middle Ear.

Too much importance cannot be placed upon the intimate relationship which exists between affections of the nose and throat and the aural cavity. The anatomical construction of these parts affords a fertile field for the spread of infections from one to the other, so that diseases of the ear owe their origin, in a large number of cases, to affections of the nasal and post-nasal spaces. The spread of inflammatory conditions of the nasal mucous membrane through the Eustachian tube often brings about pathological changes in the tympanic cavity which are of a temporary or permanent nature. A thorough knowledge of the pathology of diseases of the nasal and post-nasal regions and the anatomical construction of these parts is, therefore, all the more important to the aurist, as it is often only by the application of a proper and timely therapeutic measure that one is frequently able to prevent infections in the middle ear, and to stay the advance of pathological conditions already existing there. In a large number of cases in which there is some abnormality in the nasal chamber, the nasal breathing is interfered with, so that there is no longer a free interchange of air between the nasal and aural chambers, with the result that the hearing function becomes more or less impaired. In order to sustain the normal hearing, the pressure on the drum membrane from within, must be equal to the atmospheric pressure from without. When this balance of pressure is disturbed owing to some abnormality in the nasal or post-nasal chambers, the transmission of the sound waves from the drum to the labyrinth by way of the ossicular chain is impaired, in consequence of which there is a disturbance in the hearing of varying degree. In order, therefore, to retain the normal hearing, this interchange of air must be maintained, and can be accom-

plished only by keeping the tubes open and the nasal chambers as free from infections as possible. The impaired breathing is due in most cases to a deflected nasal septum, bony spurs, nasal polypi, new growths, and especially in children to the presence of hypertro-phied and diseased tonsils. and adenoid vegetations in the post-nasal space. The acute and chronic nasal catarrhs, the acute and chronic suppurations of the accessory sinuses of the nose, and the atrophic rhinitis or ozæna, are often the etiological factors in producing destructive changes in the tubes and tympanic cavities. In cases also, in which there is a continuous purulent nasal dis-charge, the chances of infection of the otitic cavities are greatly increased, because the secretion is readily forced through the tubes during an act of swallowing, or when blowing the nose too violently. The treatment and arrest of such suppurations often prevents the infection from spreading into the middle ear. In like manner, the treatment of a nasal catarrh does in a great measure tend to prevent the development of a catarrh of the tympanic cavity, and if already present, frequently retards its further progress. Even in cases in which there is a loss of the hearing and troublesome head noises, a proper energetic treatment of the nasal condition will, as a rule, bring about an amelioration of the annoying symptoms, and even a return to the normal. As a result of the nasal conditions stated above, the action of the muscular elements of the tubes are interfered with, so that there is an impaired ventilation of the tympanic cavities. This causes changes in the sound-conducting apparatus, which are associated with a loss of sound perception, ranging from a mild deafness to an almost complete loss of the hearing function. The removal of these obstructions whereby the free interchange of air is again re-established, does in many cases act beneficially upon the aural lesions, so that one notices within a very short time an improvement in the hearing. Such local measures furthermore tend to improve a catarrhal condition in the nasal chambers, and in this way to exercise a healthy influence upon a catarrhal condition in the middle ear. In many cases of deafness, one finds that the cause of the trouble is due to the presence of hyper-trophied and diseased tonsils, and adenoid growths in the posterior nares. This applies especially to children, who in the first years of life are subject to catarrhal and purulent inflammations of the middle ear. The adenoid, which in a large number of cases occupies the greater portion of the post-nasal space, acts as a mechanical obstruction, and interferes with the ventilation and action of the muscles of the tube. This creates an acute or chronic stasis and congestion of the bloodvessels of the mucous membrane of the tube and middle ear, with the result that there is an increased exudation in the tympanic cavity, which increases as time goes on, and leads in many cases to pathological changes which may be of a temporary or permanent nature. Such changes

may be slight or so marked that they frequently form the bases of the most pronounced disturbances in hearing. ' In addition to this, the adenoid usually gives the children a stupid appearance, interferes with their speech, and retards their mental and physical development. The anatomical structure of the adenoid deserves consideration. If one examines it carefully, one finds that it is made up of one large central lobe and two lateral lobes separated by deep furrows or clefts (Fig. 284). These are, as a rule, subdivided into smaller lobes, also separated from each other by a number of smaller clefts. They harbour the various
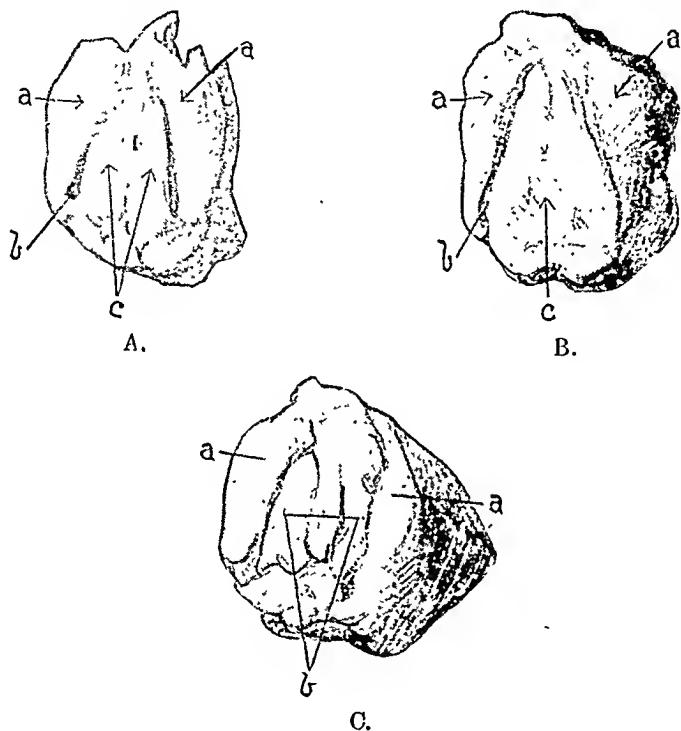
FIG. 284.—ADENOIDS (NATURAL SIZE).

A.—a, Lateral lobe; b, Cleft; c, Central lobe.
B.—a, Lateral lobe; b, Cleft; c, Central lobe.
C.—a, Lateral lobe; b, Central lobe, with multiple clefts.

forms of micro-organisms, which under favourable circumstances, migrate through the tubes into the middle ear, where they set up an inflammatory process in the form of an acute or chronic otitis media, with its far-reaching sequelæ. The thorough removal of such a mass often produces a surprisingly rapid improvement in the aural condition. Cases in which the hearing has been impaired for some time often respond with such rapidity that one notices within the shortest time a decided improvement in the sound perception, and often a complete return to the normal. In cases also in which there has been a suppuration of long standing, the

discharge ceases with astounding rapidity after a thorough cleaning out of the post-nasal space. This is due to the fact that we have removed the source of infection and have taken away an impediment which has interfered with the free action of the Eustachian tube; the interchange of air between the tympanic cavity and nasal region is thereby re-established, the power of transmission of the ossicular chain is restored, and the perception for sounds is again brought back to the normal state. That middle-ear infections are more prevalent in infants and young children is due to the fact that the tubes are shorter and wider than in the adult, so that bacteria and foreign matter (as during vomiting) reach the aural cavities more easily.

In a large number of cases the entrance of foreign substances into the middle ear causes the most excruciating pains, and gives rise to the most severe inflammatory processes. This applies especially to the entrance of water during sea-bathing. The common practice of diving and putting the head under water is associated with a certain amount of danger, and should be discouraged. The individual, when he emerges from the water, invariably blows his nose too violently, and in doing so forces the water, which is generally impregnated with particles of sand, dirt, etc., into the middle ear, where it gives rise to intense pain, and an otitis media with its usual chain of symptoms.

Syringing and douching the nose and post-nasal chambers is also a practice which should be discouraged, as it is also associated with a certain amount of danger. If not used properly, fluids are easily forced into the tympanic cavities, causing intense pain, and giving rise to various otitic complications. It is therefore advisable, when it is desired to medicate or cleanse the nasal regions, to apply the medicaments in the form of sprays or vapours. By doing so one avoids unnecessary pressure, there is no excess fluid in the post-nasal space which can be forced through the tubes, and the drug is gently disseminated over the entire mucous membrane.

That operative procedures on the nose and throat should always be carried out under the strictest aseptic precautions is self-evident, for one sees at times severe otitic complications develop shortly after such intranasal manipulations. This is particularly so when the nasal chambers are packed with tampons which are allowed to remain too long. It is therefore advisable, where possible, to dispense with such tampons, and in this way to minimize the danger of infection. It is impossible in a book which is devoted entirely to diseases of the ear and its adjacent structures to go into the pathology and treatment of the nasal and post-nasal conditions, but it is mainly the author's purpose to call attention, as already stated, to the intimate relationship which exists between nasal and aural affections, and to impress upon the practitioner the important fact, when treating otitic conditions,

that a favourable outcome can be obtained in the majority of cases only if a simultaneous treatment is applied to the nose and throat. For the therapy and operative technic of nasal and post-nasal affections, and the various anomalies of formation, the reader is referred to the large number of splendid textbooks devoted to this special branch of medicine.

The Diseases of the Labyrinth, of the Auditory Nerve, and of its Central Course.

Introduction.

Our knowledge regarding the pathology of the sound-perceiving apparatus is still very imperfect, in spite of the numerous scientific investigations which have been undertaken in the last few years. This is most easily explained by the fact that we are seldom in a position to make a thorough anatomical *post-mortem* examination of the ears of those individuals who have been known to have been afflicted with a diseased condition of the auditory nerve apparatus during their life.

We therefore see the difficulty in giving a description of diseases of the internal ear which agree with the clinical observations. A satisfactory study of this subject will be possible only when further clinical observations can be made to correspond with the conditions found at the *post-mortem*.

The diseases of the internal ear are primary, and secondary, and are divided, according to their location, into affections of the cochlear and vestibular apparatus. The primary forms are much more rarely met with than the secondary.

Etiology.—The diseases of the internal ear either arise idiopathically without any discoverable cause, or they are produced by external harmful influences (cold, sunstroke, diving into the water, traumatisms, concussions) and by general and organic affections. It is, however, mainly through affections of the tympanic cavity that secondary pathological changes are produced in the internal ear. These changes must not, however, always be regarded as secondary, as there is no doubt that the infection in both parts is frequently occasioned by the same cause.

The idiopathic affections of the auditory nerve apparatus, among which may be reckoned primary hæmorrhages and inflammations, are, on the whole, rare.

The following are the external harmful influences which bring about a temporary or permanent disturbance in the function of the auditory nerve apparatus: The action of intense sounds (explosions, detonation); indirect injuries to the labyrinth, injuries to the skull (fall on the head, fall, blow, and concussion), and injuries of the labyrinth occasioned by sudden changes of air-

pressure, as in caisson-workers, aeronauts, and divers (see p. 637). We must also add here labyrinthine disturbances of hearing which are caused in persons who have certain occupations, as blacksmiths, locksmiths, plateworkers, coppersmiths, coopers, engineers, and stokers, etc.

Temporary or permanent disturbances of hearing following affections of the mind, after a fright, or after great grief, have been frequently reported. This is explainable if one considers that affections of the mind are amongst the most prominent causes acting upon the vaso-motor nerves (vaso-constriction and dilatation), and that therefore, owing to sudden changes in the circulation of the vessels supplying the acoustic nerve and its terminations, disturbances of nutrition (ischæmia, hyperæmia, stasis) can be brought about which manifest themselves in symptoms of irritation or paralysis.

It is also well known that the auditory nerve is more often affected than any of the other nerves of special sense by the action of drugs circulating in the blood. One must only take into consideration the action of such medicaments as quinine, salicylic acid, morphine, chloroform, tobacco, alcohol (Alt), and the oil of chenopodium, which exercise a temporary, often, however, a permanent, influence on the function of the auditory nerve. These drugs frequently cause subjective noises and deafness of a varying degree when used in large doses or for a long time. The auditory nerve is particularly predisposed and sensitive to the action of quinine, which first makes itself evident by subjective noises and by a diminution in the hearing, which usually takes place within one to three hours. One should use this drug with discretion, as some patients have a marked idiosyncrasy against it. Its predilection for the auditory nerve often causes the most severe pathological changes, leading to deafness of a varying degree, and even to a permanent loss of the hearing function in one or both ears.

Kirchner (*Berl. klin. W.*, 1881), who administered quinine to rabbits, found hyperæmia and hæmorrhages in the mucous membrane of the tympanic cavity and in the labyrinth. Wittmaack (*Archiv f. d. ges. Physiologie*, vol. xcv.) found marked changes in the ganglion cells of the ganglion spirale and vestibulare.

Other toxines having a paralyzing effect on the auditory nerve are: Lead, mercury, arsenic, and carbon disulphide which begins with headache, vomiting and tinnitus, and is met with in workers of hard rubber; chronic aniline poisoning; and necrosis of the temporal bone due to the action of phosphorus.

Diseases of the middle ear are the most important factors in bringing about secondary pathological changes in the auditory nerve apparatus. Sero-mucous catarrhs and primary inflammations of the middle ear are seldom associated with a

simultaneous affection of the labyrinth. If, however, this is the case, it is due, either to an increased labyrinthine pressure, to the action of toxines, or to a secondary suppurative infection of the labyrinth (see p. 556).

In the chronic non-purulent middle-ear processes, the labyrinth does not become affected, except in rare cases (to which we must especially reckon the syphilitic catarrhs). In the long-standing catarrhal adhesive processes, however, and in otosclerosis (see p. 331), retrogressive changes develop in the labyrinth, which cause a high degree of hardness of hearing.

The labyrinth is seldom involved in the uncomplicated chronic middle-ear suppurations. In carious processes, especially if the cells in the region of the labyrinthine capsule are affected, one not infrequently finds ecchymoses in the semicircular canals and in the cochlea. In reference to the suppurative inflammations of the labyrinth in chronic middle-ear suppurations, the reader is referred to the chapter on Labyrinthine Suppurations (p 550).

Diseases of the brain and its membranes play an important part in bringing about secondary affections in the auditory nerve. The following, which often occasion a marked form of deafness, may be especially mentioned: Epidemic cerebro-spinal meningitis, hydrocephalus, acute and chronic encephalitis, brain tumours, and less often diseases of the spinal cord.

Those general and infectious diseases, as typhoid and scarlet fever, measles,* diphtheria, influenza,† intermittent fever, osteomyelitis infectiosa, syphilis, leucæmia, pernicious anæmia, diabetes, Bright's disease, and morbus maculosus (Werlhoffii), must also be regarded as frequent causes of disturbances of hearing, owing to their influence upon the auditory nerve; these diseases cause disorders in the auditory centre (œdema of the intracranial course of the acoustic, Rosenstein), or in the terminal endings of the nerve, either by the production of secondary inflammatory or hæmorrhagic exudations, or by the action of the blood which has undergone pathological changes.

It must, however, be mentioned, that the auditory nerve is more readily injured and possesses the greatest impressionability of all the cranial nerves—that is, its function is much more often arrested by general diseases and chemical changes in the blood during infectious diseases, than any other of the cranial nerves.

The anatomical changes in the auditory nerve apparatus, arising during the course of infectious diseases, are not yet well understood. Hyperæmia and ecchymoses, small-cell infiltration and suppurative inflammation of the labyrinth, ending in the

* Moos, *Untersuchungen über Pilzinvasion des Labyrinthes im Gefolge von Masern*, Wiesbaden, 1868.

† Lannois, *Surdité labyrinthique consécutive à la grippe*; J. Moure, *Revue de Laryngologie, d'Otologie*, etc., Paris, 1890.

new formation of connective tissue and bone, have been most frequently found.

A great number of cases have been reported in which the function of the auditory nerve was quickly arrested and in which there was complete deafness as a result of an attack of mumps (parotitis epidemica); it has not been possible, however, to establish the anatomical cause of this severe, afebrile, incurable nerve condition which arises after a parotitis and without any attacks of dizziness or disturbances in equilibrium. The hypothesis that the deafness in mumps is caused by an acute exudation or metastasis in the labyrinth (similar to affections of the kidneys, ovaries, mammæ, testicles), or by an affection of the acoustic centre, has not been substantiated. It is most probable that this form of deafness is due to a toxæmia.

Of the pathogenic micro-organisms, the streptococcus, more rarely the staphylococcus, and the pneumo-diplococcus have been found in the labyrinth. The path by which these organisms most frequently enter the labyrinth from the cranial cavity is by way of the aquæductus cochleæ. They cause either a rapid destruction of the connective tissue, or they lead to the formation of new connective tissue and bloodvessels, which results in the new formation of bone. In addition to this, they produce, in cases of measles and in simple and diphtheritic scarlet fever, a thrombo-arteritis and phlebitis with their sequelæ, which are evident as hæmorrhages along the sheaths of the main nerves, with destruction of the nerve elements.

It cannot be denied that there is a correlation between organic affections and the organ of hearing. It is certain that, in the course of chronic organic diseases, nutritional disturbances of the general system develop in consequence of anæmia, hydræmia, and marasmus, which have not only a deleterious influence upon the entire system, but also upon the auditory nerve, whose power of resistance is lowered.

Many observations have recently been published showing the relation of diseases of the sexual organs to those of the ears. Bonnier, Eitelberg, and others consider masturbation, especially in females, an important factor in influencing the course of aural affections. Benni saw several cases of vicarious exudation and hæmorrhage from the middle ear when menstruation was suppressed. Baratoux (*Des affections auriculaires et de leurs rapports avec celles de l'utérus*, Paris, 1881) came to the conclusion that in those cases in which there is a purulent middle-ear suppuration, the local affection is aggravated through menstruation, and that in amenorrhœa, vicarious hæmorrhage may take place from the ear. In addition to this, attacks of dizziness combined with subjective noises and a feeling of tightness in the head have been observed in consequence of suppressed menstruation and at the beginning of the menopause, which could be attributed to a congestion of the bloodvessels in the labyrinth. It is well known that disturbances of hearing may arise, or those already existing become more marked, during pregnancy and after parturition (see p. 467).

Functional disturbances of the auditory nerve are also caused by impaired circulation of the cranial vessels. Frequently, however, disturbances of hearing may be traced to diseases of the heart and lungs, and to some forms of goitre.

It cannot be denied that hereditary predisposition plays an important part in the production of affections of the acoustic nerve, as is evident in cases of hereditary deaf-mutism. On

the whole, however, it seems to be less often the cause here than in otosclerosis.

Diseases of the internal ear are met with more often in children than in adults. This is explained by the fact that such diseases, as the acute exanthemata, diphtheria, acute hydrocephalus, epidemic cerebro-spinal meningitis, etc., which occur so frequently in children, are often associated with affections of the ear. Moreover, it must be brought to notice that the anatomical relationship between the middle ear, labyrinth, and cranial cavity is more pronounced in children than in adults; and further that, by means of the aqueducts, there is a more extensive communication between the fluid of the labyrinth and the cerebro-spinal space in children than in adults.

The frequency of affections of the auditory nerve diminishes in middle age, but increases again considerably in the later years of life, especially after the sixtieth year. The anatomical causes of this disturbance of hearing in old age, is found to be due not only to changes in the labyrinthine capsule which lead to ankylosis of the stapes (otosclerosis), but also to retrograde changes, such as atrophy, fatty degeneration, and chronic endarteritis in the auditory nerve and its terminations (senile degeneration).

In the majority of cases, both auditory nerves are affected, either simultaneously or at a shorter or longer interval. The condition seldom remains localized to one ear. According to the author's experience, this is most frequently the case in unilateral affections of the acoustic nerve produced by the action of an intense noise. It has been found that in these unilateral acoustic disorders, just as in middle-ear diseases, the danger of the affection extending from one ear to the other is all the greater the higher the degree of impairment in hearing. It has not yet been established in what way the affection of one ear extends to the other. The anatomical relation of the acoustic nuclei allows us to presume, with probability, that degenerative processes of the one auditory nerve may affect the centre and root of the nerve of the opposite side.

Symptoms.—In affections of the internal ear, we must distinguish between symptoms produced by lesions in the cochlear and those in the vestibular apparatus. The symptoms of the cochlear apparatus are apparent in irritation and paralysis. To the former we must reckon subjective noises, hyperæsthesia acustica, and the electric irritability of the auditory nerve; to the latter, a nerve hardness of hearing, or deafness. The symptoms of irritation of the vestibular apparatus due to abnormal irritability of its function are made evident by the appearance of vertigo, nystagmus, and disturbances in equilibrium. A paralysis of the vestibular apparatus is manifested by a diminished or lost irritability.

The disturbances of hearing accompanying diseases of the internal ear develop either rapidly or progressively. In some forms of disease—as, for instance, in the apoplectic forms of Menière's disease, in labyrinthine syphilis, in cerebro-spinal meningitis, and in traumatic concussions of the labyrinth—the hearing is often suddenly lost, or disappears entirely within a few days. In other chronic forms, on the other hand, the hearing diminishes gradually, but not uniformly, however. Greater intervals, in which the hearing remains stationary, may be followed by a period during which the deafness progressively increases, or the slow course of the disease may be interrupted by sudden exacerbations.

Variations in the acuteness of hearing are, as a rule, much less often met with in diseases of the acoustic nerve than in affections of the middle ear. These variations are influenced by external harmful conditions, bodily indisposition, mental excitement, insomnia, over-indulgence in alcoholic beverages, etc.

We must add here a group of symptoms due to labyrinthine affections, known as Menière's symptom-complex (called *vertigo ab aure lœsa*, by the older authors). These symptoms, which take their origin from the vestibular apparatus, are brought about either by primary changes in the labyrinth itself, or as the result of pathological conditions in the sound-conducting apparatus.

The irritability of the vestibular apparatus may be preserved, increased, or entirely lost. According to the etiological factors producing these conditions, we may distinguish two groups.

In the first group belong all affections of the external (cerumen, polypi), middle (otitis media acuta, catarrhal adhesive processes, otosclerosis), and internal ear, in which vertigo, nystagmus, and disturbance in equilibrium arise in paroxysms, and in which examination reveals a normal or increased irritability. The assumption that this symptom-complex occurring with middle-ear affections is caused by an increased labyrinthine pressure arising from the middle ear is true only in those cases in which there is a marked retraction of the membrana tympani, and in which the symptoms of labyrinthine irritation disappear, or are considerably improved, after an inflation of air or after tenotomy of the tendon of the tensor tympani muscle.

In the large majority of cases, however, there is a congestion or exudative process in the labyrinth (also anæmia) which occasionally arises during the course of the middle-ear affection, and which causes the so-called symptom-complex by irritation of the vestibular and ampullar nerves.

We know that the extension of an affection of the middle ear to the labyrinth calls forth vestibular symptoms, yet it sometimes happens that such symptoms also arise in the rare primary affections of the labyrinth. The causes of such labyrinthine disturbances are assumed to be intercurrent hyperæmias, ecchy-

moses, exudative processes, and anæmia; these conditions usually act upon the vestibular apparatus, but often also involve the cochlea. That the latter has become affected can be concluded from the marked disturbance in hearing which arises simultaneously with the vestibular symptoms.

The symptoms of irritation which occur with middle-ear and labyrinthine affections show a most varied gradation, from a simple feeling of vertigo, which lasts only a few seconds and causes hardly any annoyance, to the most severe attacks of dizziness, which usually arise at irregular intervals.

The attacks recur either without any apparent cause or from physical exertion, by turning the head rapidly, from bending over or standing up suddenly, after a hearty meal, from excesses, after nervous excitement, mental affections, etc. A new attack is often preceded by marked tinnitus, a feeling of pressure and heaviness in the head, a mental depression, and sensations of turning. With the attack of dizziness there is usually a nystagmus towards the diseased side, the intensity of which depends on the severity of the attack.

The duration of the attack varies from a few seconds to several hours. While some patients recover quickly, others feel languid and faint, dizzy and uncertain in gait for some time. The attacks, which often are absent for years, may recur, and not infrequently, even after having existed a long time, may end in complete recovery. In other cases there is a gradual diminution or loss of function of the vestibular apparatus, in that the attacks become lighter and their intervals greater, until, after complete destruction of the vestibular apparatus, they cease entirely.

It must be mentioned that the patients in whom the attacks come on even at long intervals are not entirely free from vertigo and unsteadiness in gait during the interparoxysmal stage, and that a decided neurasthenia develops after oft-repeated attacks.

The second group of affections of the labyrinth takes in the diseases which are followed by a sudden loss of function of the vestibular apparatus. These comprise the acute labyrinthine suppurations, the apoplectic form of Menière's disease (hæmorrhage into the internal ear), and the traumatic lesions of the internal ear. The intensity of the symptoms varies according to whether the anatomical changes in the vestibular apparatus develop rapidly or slowly. The violent symptoms are most fully developed in the apoplectic form of Menière's disease, and in injuries of the labyrinth produced by operative procedures or traumas. The nystagmus towards the healthy side is, in these cases, produced by the vestibular apparatus on the healthy side. In the severe attacks, dizziness, tinnitus, and vomiting are almost always present. Every attempt to change the position of the body or to get up increases the nystagmus and the subjective symptoms. The face is pale, the expression languid, the skin

covered with a cold sweat, and the pulse small, often retarded. In attempts at walking or standing, the patients fall towards the affected side. The vestibular apparatus of the affected side no longer reacts to caloric irritation (Bárány). The severe symptoms do not, as a rule, last long. After several days the vomiting ceases, the dizziness abates considerably or ceases entirely, and the nystagmus and disturbances in equilibrium also are greatly diminished. When the nystagmus has disappeared, or is still very ·slight, the labyrinthine affection has entered the latent stage. The caloric and galvanic tests show no reaction at all on the affected side. When rotating the patient towards the diseased side, one finds, after ten revolutions, a more marked and longer (about thirty seconds) nystagmus than when rotating the patient towards the healthy side (about fifteen seconds) (Bárány).

One must distinguish aural vertigo from that caused by refraction anomalies of the eyes, and by paralyses of the ocular muscles; furthermore, from that observed in acute and chronic infectious diseases, in toxic infections (alcohol, nicotin, quinine, salicylic acid), in disorders of the stomach, in disturbances of the circulation (anæmia, arterio-sclerosis, heart-failure, etc.), in nephritis, diabetes, tuberculosis, in nervous affections (neurasthenia, hysteria, hemicrania), as aura of an epileptic attack, in cerebral and cerebro-spinal affections (brain tumours, multiple sclerosis, progressive paralysis, tabes), and in traumas. The vestibular symptom-complex occasionally observed in individuals with normal ears is termed ' pseudo-Menière ' by v. Frankl-Hochwart.

The Diagnosis of Diseases of the Auditory Nerve Apparatus.

The diagnosis of a diseased condition of the auditory nerve presents great difficulty in many cases. This not only applies to the differential diagnosis between diseases of the middle ear and auditory nerve apparatus, but also to those cases in which an affection of the nerve apparatus has been established, as it is often impossible to determine whether the lesion has its seat in the labyrinth itself, in the root of the nerve, or in its central course. In addition to this, middle-ear and labyrinthine diseases are often combined, and it is not possible to decide in such cases how much of the disturbance of hearing is due to the middle-ear disease, or to the affection of the labyrinth.

The diagnosis of disorders of the auditory nerve is made chiefly from the presence of certain symptoms, and from the results of the functional tests. The greatest importance must be attached to the latter, because in the majority of cases in which the ocular examination yields a negative result, and in which the Eustachian tube is permeable, only the functional tests allow us to assume that we are dealing with an affection of the acoustic nerve.

The details of the hearing tests have already been given in the

chapter on Tests for Hearing (p. 140).   In order to avoid repetition, only the most important data for making a diagnosis will be mentioned here.

Testing with the watch and acoumeter in diseases of the acoustic nerve does not inform us as to the hearing distance for speech. As a rule, however, when the deafness is slight, speech is perceived at a relatively greater distance than the watch. A diminished perception for the watch through the cranial bones cannot always be considered a symptom of a diseased condition of the auditory nerve.*   Where, however, a loud-ticking watch or acoumeter is perceived faintly or not at all through the cranial bones, it is justifiable to assume that there is a diminution in the power of perception of the auditory nerve apparatus.   Testing with the tuning-forks is more important, and especially with the low C^{-1} and c.   Examination shows here that frequently even when there is a marked disturbance in hearing, the perception for the lower range is less impaired than in analogous disturbances in hearing brought about by an obstruction in the sound-conducting apparatus.

On the other hand, testing with high tones has only a limited use.   When the diagnosis of a nerve affection has been positively established, there is sometimes a complete loss of perception for high tones; such a result, taken in conjunction with the perception for low tones, is of great value in helping us make the diagnosis of an affection of the auditory nerve.   It frequently happens, however, in cases of marked, uncomplicated disease of the sound-perceiving apparatus, that high tones are perceived nearly to the highest range of the scale, in addition to the perception for low tones.†

When we are dealing with a case of unilateral disturbance of hearing (Weber's test, p. 155), and the tone of the vibrating tuning-fork placed on the vertex is localized towards the normal ear, it can be assumed that there is an affection of the labyrinth only if, at the same time, the results of Rinne's test, testing the perception for high and low tones, and the entire symptom-complex indicate a diseased condition of the auditory nerve apparatus.

If Rinne's test is positive, and the hearing power for speech is greatly reduced, we can assume with great probability that there is an affection of the internal ear; the result of Rinne's test, (p. 157), must, however, always be taken in conjunction with the results of the other methods of examination in making a diagnosis of an affection of the auditory nerve.

A strikingly shortened perception for the c^2 tuning-fork

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* This applies only to individuals who have not passed their sixtieth year.

† Pansc (*Archiv f. Ohrenheilk.*, vol. lix.) found in a number of cases examined clinically and anatomically, in which there was an atrophy of the basal ganglion cells, that the perception for the high and highest tones was preserved.

through the cranial bones (Schwabach's test, p. 153) is an important factor in establishing a diseased condition of the sound-perceiving apparatus, if taken in conjunction with the positive results of the tuning-fork tests just given above.*

Gellé's test (p. 159) can be used as a means of establishing the diagnosis of an affection of the labyrinth, in cases of marked deafness, only if severe dizziness and an increased perception for the tone of the tuning-fork are produced under a centripetal pressure of even moderate degree. Both may be absent when there is a marked disease of the labyrinth.

The result of the examination with musical tones often agrees with that obtained by means of the tuning-fork; when testing the perception, however, for low and high tones with different musical instruments, it is not infrequently found that the results are completely opposite.

Bezold's series of tuning-forks (p. 143), in addition to Galton's whistle, are recommended as means by which partial tone defects may be ascertained.

Moos observed, in a leader of an orchestra, sudden deafness for low tones, which was due to a sudden concussion of air acting upon both ears (bass-deafness). Schwartze saw in a musician (Robert Franz) permanent loss of perception for high tones, and later total deafness, follow the action of the noise of a locomotive whistle; Burnett observed deafness for high tones above c''' in a woman forty-four years of age who had suffered from otalgia since her childhood; and Gottstein likewise met with a man forty-seven years of age who had also lost the perception for high tones from $\bar{c}$ upwards. In the case of an orchestra director, fifty-one years old, who had been examined by the author, ringing and buzzing in the ears had been present one year previously; subsequent attacks of dizziness came on, and total deafness rapidly developed, first in the right and then in the left ear. Testing with musical tones showed that the patient heard only the low tones with the left ear and the entire scale with the right, but that in the latter b and f of the middle range were completely lost. Knapp observed deafness for a group of tones in several cases of Menière's disease. Grönlund (*Archiv f. Ohrenheilk.*, vol. lvii.) found in a fifteen-year-old patient who became deaf suddenly that speech was perceived only as a noise, and a loss of perception for b_2-g^1 on the right side, for d-d^1 on the left side, and, furthermore, for C_2-F_2 on both sides. The loss of perception for single tones in the middle range of the scale is, on the whole, very rare. If the ear in such cases is provided with the corresponding Helmholtz resonator, it will be found that there is seldom total deafness, but only a diminished perception for that particular tone. Tone defects are often found in the upper, seldom in the lower, range of the scale. Bezold observed several cases of total deafness in which there was still perception for single tones of the upper scale, which he termed auditory islands (*Hörinseln*). Although tone defects show that there is probably an affection of the acoustic nerve, still

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* Urban Pritchard (*Manual of Diseases of the Ear*, London, 1886) uses a small tuning-fork devised by Gardiner Brown, by means of which the difference of time is measured in which the patient fails to perceive the tone, and the physician no longer feels the vibrations with his finger. If the patient perceives the tone longer than the person examining can feel the vibrations, it can be taken for granted that the disturbance of hearing is due to some condition obstructing the sound conducting apparatus; but if the reverse is the case, it points towards an affection of the labyrinth.

they do not exclude the simultaneous existence of some condition obstructing the sound-conducting apparatus. This is seen from a case reported by Magnus (*A. f. O.*, vol. ii.), in which the tones f, $f\sharp$, g, $g\sharp$, $a\sharp$, and b in the scale beginning with c below the staff to the octave above, were not heard, and in which the *post-mortem* examination of the ear showed ankylosis of the stapes and calcification of its foot-plate. The more minute details of the finer changes in the labyrinth in this case were not given. Frankl-Hochwart several times observed false perception for tones in cases with Menière's symptom-complex.

The speech tests are of little value in making the diagnosis of an affection of the labyrinth. According to O. Wolf (see p. 148), the failure to perceive f, r lingual and whispered u, and, according to Bezold, the non-perception of some numerals, is supposed to indicate an affection of the auditory nerve apparatus. Total deafness for speech is no positive sign of an acoustic disorder, inasmuch as cases are met with in which the hearing power for speech, which is completely absent, again returns for a short distance after an inflation of air or after the application of an artificial drum membrane; this, therefore, demonstrates that the deafness was partially caused by an increased labyrinthine pressure owing to some abnormal condition in the tympanic cavity. Nevertheless, total deafness for speech, taken in conjunction with the other symptoms, is an important factor in establishing the diagnosis of a labyrinthine affection.

The examination of the membrana tympani and Eustachian tube is of diagnostic value in determining an affection of the auditory nerve only in recent cases and when the appearance of the membrane is normal. If in cases of sudden marked deafness the membrane has a normal appearance and the tube is permeable, it may be concluded with great probability that the loss of hearing is caused by an affection of the auditory nerve, particularly if the other results of examination also point in that direction. On the other hand, visible structural changes on the membrane, such as opacities, slight retractions, and absence of the light reflex, do not, however, exclude the possibility of an uncomplicated affection of the auditory nerve apparatus.

The assumption that, in uncomplicated affections of the sound-perceiving apparatus, no alteration in the hearing distance is obtained by an inflation of air is not true, as the author has seen cases in which the objective examination and all the symptoms pointed to an affection of the labyrinth, and in which a striking increase, less often a diminution, in the hearing distance was obtained after an air douche. This is readily understood if one takes into consideration that the air douche produces variations of pressure in the labyrinth by changes of tension in the middle ear, which influence the acuteness of hearing. As a rule, however, the changes in the hearing distance obtained by the air douche are much more limited in affections of the labyrinth than in diseases of the middle ear.

The author has also observed a striking improvement in the hearing, a diminution in the troublesome noises, and a subjective feeling of relief, follow rarefaction of the air in the external meatus. On the other hand, it is found that condensation of the air in the external meatus and the various forms of massage often produce a feeling of tightness in the head, dizziness and deafness, and should therefore not be employed in uncomplicated affections of the sound-perceiving apparatus.

In reference to the diagnosis of affections of the vestibular apparatus, the reader is referred to the methods of examination (p. 164) and the symptoms of its functional disturbances.

The differential diagnosis of affections of the separate portions of the labyrinth is still very difficult. Wittmaack (*Zeitschr. f. Ohrenheilk.*, vol. l.) assumes that in affections of the labyrinth there must always be symptoms arising from the cochlear and vestibular apparatus; an isolated affection of one or the other portion of the labyrinth is hardly likely to occur. True disturbances in hearing without vestibular symptoms may, therefore, always be traced to a primary, usually toxic, affection of the ramus cochlearis, with a secondary degenerative change in the cochlea—a view which is contrary to the most recent clinical examinations and conditions found *post-mortem.*

It must finally be mentioned that, in all disturbances of hearing in which the symptoms give rise to a suspicion of a disease of the central nervous system, we must always make a thorough examination of the entire body for sensory and motor disturbances, of the parts innervated by the cranial nerves, of the tendon reflexes, and of the fundus of both eyes, pupils, etc.

The terminations of affections of the internal ear depend on the etiology, on the bases of the pathological condition, and on the state of the general system of the patient. That some diseased processes in the labyrinth and auditory nerve can recede with a complete restoration of the hearing function is beyond doubt. On the whole, however, a return to the normal is much less frequent than in the middle-ear affections. Hyperæmia in the labyrinth, serous infiltration of its structures, and capillary ecchymoses, may disappear completely, without leaving any disturbance in the hearing. On the other hand, it can be assumed, from clinical experience, that extensive changes, such as suppurative and non-suppurative inflammations, severe hæmorrhages, profuse invasion of micro-organisms, new formation of connective tissue and bone, the regressive changes in the auditory nerve (atrophy, fatty and colloid degeneration), and so forth, lead to a more or less rapid disorganization of the acoustic nerve, which is not capable of restitution, and which is associated with a loss of the hearing function.

The prognosis of affections of the auditory nerve apparatus depends on the etiology, the duration, and the intensity of the disease. It is, on the whole, regarded as unfavourable. This applies especially to the apoplectic form of deafness which arises

suddenly, to labyrinthine affections which develop after the infectious diseases and after cerebro-spinal meningitis, to a panotitis, and to the cerebral disturbances of hearing.

The prognosis is more favourable in recent rheumatic paralyses, in paralyses of the acoustic nerve brought about by drugs, in some forms of hysterical deafness, in mild concussions of the labyrinth, and to a limited degree in the syphilitic affections of the internal ear.

The Diseases of the Auditory Nerve Apparatus.

I. Hyperæmia of the Labyrinth.

Hyperæmia of the labyrinth is rarely confined to this portion of the ear alone, but is usually associated with congestion of the middle ear and cranial cavity.

According to clinical and anatomical observations, intense hyperæmia of the labyrinth is observed in acute purulent middle-ear inflammations which arise with violent reactive phenomena; this applies especially to those forms arising in the course of scarlet fever, diphtheria, and typhoid fever. At the *post-mortem* examination of such cases, the author found the congestion most marked on the external labyrinthine wall and in the first turn of the cochlea. It is a rare occurrence to find this congestion extending uniformly over the entire lining membrane of the labyrinth, the utricle and saccule, the semicircular canals, and the lamina spiralis.

The following may be regarded as further causes of labyrinthine hyperæmia: The acute exanthemata, typhoid fever, mumps, pneumonia, meningitis, encephalitis, puerperal fever, and tumours at the base of the brain, which arrest the flow of blood from the labyrinth by pressure upon the veins coming from the internal meatus; furthermore, thrombi in the blood channels of the petrous portion of the temporal bone and in the internal jugular vein, congestion of the head in consequence of goitre, heart and lung affections, angioneurotic congestion of the cranial vessels, and, finally, the use of certain drugs, as for instance, amyl nitrite.

Congestion in the labyrinth produces temporary disturbances of hearing or permanent anatomical changes, which vary according to its intensity and duration. Such anatomical changes, which are so frequently met with in chronic middle-ear inflammations, are recognized as abundant deposits of pigment in the labyrinth, accumulations of calcareous salts, and thickening of the membranous structures of the labyrinth.

Clinical Symptoms.—The clinical symptoms of labyrinthine hyperæmia are: Subjective noises, dizziness, a feeling of fulness in the ears and tightness in the head, nausea, tendency to vomit,

and unsteady gait. When there is a sensation of dazzling before the eyes, deafness, and a feeling of heaviness in the head, it is probable that the hyperæmia of the ear is part of a hyperæmia of the brain. With these symptoms of congestion, the inner portion of the osseous meatus and the vessels along the handle of the malleus are not infrequently found injected, which indicates a general hyperæmia of the entire organ. This is occasionally associated with redness of the face and auricle. Hyperæmia of the internal ear may exist, however, without any apparent injection of the external ear and membrana tympani. In the congestive forms the hearing is altered to a slight degree; this, however, is usually only of a temporary nature.

Diagnosis.—The diagnosis of hyperæmia of the labyrinth may be made with probability if, in addition to the above-mentioned subjective symptoms, examination with the speculum reveals a congestive condition of the ear. Hyperæmia of the labyrinth, which is associated with temporarily recurring congestion of the brain, is distinguished from Menière's disease, with which it presents great similarity, in that the symptoms rapidly subside without leaving any permanent disturbances of hearing.

The differential diagnosis between hyperæmia of the labyrinth and of the brain is made with more difficulty, as similar symptoms can be produced by brain congestion—that is to say, by irritation of the acoustic centre. We may, therefore, conclude that there is a hyperæmia of the labyrinth only if the objective examination shows congestion of the ear; it must also always be borne in mind that there may be a simultaneous hyperæmia of the brain, which may give rise to the same combination of symptoms.

In acute inflammations of the middle ear it may be assumed that there is also a co-existent hyperæmia of the labyrinth if, in addition to severe subjective noises, there is marked deafness, if the perception for the watch and acoumeter through the cranial bones is lost, and if these symptoms do not immediately disappear after an inflation of air or after the removal of secretion from the tympanic cavity, but subside only in the further course of the affection as the inflammation in the middle ear diminishes.

Labyrinthine hyperæmia developing in the course of the infectious diseases cannot, as a rule, be diagnosed. We can presume only at a later stage that the disturbance of hearing was due to a hyperæmia of the labyrinth or of the acoustic centre (possibly from a serous saturation and small-cell infiltration) if the hearing power returns to normal during convalescence.

Treatment.—The treatment of hyperæmia of the labyrinth depends on the cause. It is advisable to keep the patient at rest, and have him lie in bed with the head raised. Furthermore, it is recommended to apply ice-bags or cold compresses to the head, to use alcoholic embrocations behind the

auricle (spiritus aromaticus, spiritus formicar., Hoffmann's balsam, āā 30·0), to take warm foot-baths, to keep the bowels open, and, finally, in the case of plethoric patients, to induce local bleeding at the mastoid process. Sometimes the application of a cup to the nape of the neck is sufficient to remove the dizziness and tinnitus. As the attacks recur at longer or shorter intervals, all harmful influences must be guarded against which might occasion a return of the congestion. It is advisable, therefore, for such patients to lead a regular life, to take daily exercise in the open air, to live on a simple, easily digested diet, and to use alcohol and tobacco as little as possible. If the patients are troubled with constipation, mild saline purges may be given. Sometimes cold spongings prove beneficial, while, on the other hand, cold douches to the head have an injurious effect. The application of the galvanic current to the sympathetic nerve of the neck is indicated in the angioneurotic forms. When the subjective noises predominate, large doses of sodium or potassium bromide render good service.

Acting on the idea that the disturbances of hearing running their course with dizziness and tinnitus are caused by an increased labyrinthine pressure, Botey (*Ann. des malad. de l'oreille*, etc., 1890) is supposed to have obtained a favourable result by puncture of the membrane of the round window, and by aspiration of the labyrinthine fluid with a peculiarly constructed cannula. Forns (*ibid.*) questions the practicability and efficacy of this procedure, which had previously been performed by Cozzolino (1889).

II. Anæmia of the Labyrinth.

Anæmia of the labyrinth is usually part of a general anæmia. The symptoms of irritation and paralysis of the auditory nerve apparatus which are produced by it, usually appear after the sudden loss of a large quantity of blood, after severe hæmorrhages associated with parturition, in pernicious anæmia, in osteomyelitis (Wagenhäuser, *A. f. O.*, vol. xlvi.), after severe, acute diseases, less often in chlorosis, and in cases of anæmia due to chronic affections. Anæmia of the internal ear, in consequence of an angioneurosis (angiospasm) due to some disorder of the sympathetic nerve, is an extremely rare occurrence, and will again be referred to when we come to speak of neuroses of the acoustic apparatus (p. 693).

An anæmia of the labyrinth may be produced by an impaired circulation of the internal auditory artery.

The anatomical causes of such an obstruction are: Aneurisms of the basilar artery, neoplasms which have grown from the dura mater or from the brain into the internal auditory canal, thus compressing the internal auditory artery, emboli of this blood-vessel, and constriction of the internal auditory artery due to atheromatous deposits. It is probable that in old individuals

this chronic endarteritis not infrequently extends to the vessels of the labyrinth, and forms the foundation of disturbances of hearing.

Morpurgo and the author saw a man seventy years of age who had suffered for a number of years from severe subjective noises which had been associated with a moderate degree of deafness; death was suddenly caused by rupture of the aorta, and it was found that, in addition to an extensive endarteritis, there were also deposits in the basilar artery from which the process extended to the internal auditory artery.

Disturbances of hearing arising in the course of severe hæmorrhages may be traced to a simultaneous anæmia of the organ of hearing and of the central nervous system. In cases of pernicious and simple anæmia, anatomical changes, such as hæmorrhages into the labyrinth, have been found. In a case of deafness following a severe hæmorrhage, as observed by Urbantschitsch, no anatomical changes could be discovered in the brain or in the ear itself. Schwabach (*Zeitschr. f. Ohrenheilk.*, vol. xxxv.) found, in a case of pernicious anæmia in which there was hardness of hearing, a hæmorrhagic extravasate in the middle ear, while the labyrinth and auditory nerve were, however, intact.

Symptoms.—The symptoms of anæmia of the labyrinth after sudden marked hæmorrhages, and of the angioneurotic form, are: Striking paleness of the face, intense tinnitus, and marked deafness, which are accompanied by dizziness, fainting spells, and vomiting. The symptoms as a whole resemble those of sea-sickness, and may be partially traced to a co-existing anæmia of the brain. The phenomena recede more or less quickly with the disappearance of the anæmia. Subjective noises and deafness are the main symptoms in those disturbances of hearing associated with chronic general anæmia. Their intensity depends on the condition of the bloodvessels of the head, and on the congestion produced by joyful emotions; they are also influenced by the indulgence in alcoholic beverages, and by the position of the patient, especially when he lies on his back.

Treatment.—The treatment of anæmia of the labyrinth depends on the cause. The aural symptoms which arise after a considerable loss of blood do not require any local treatment, as they recede with the disappearance of the general anæmia. In the angioneurotic forms, the internal administration of sodium or potassium bromide and quinine, and the application of the galvanic current to the sympathetic nerve of the neck, have proved beneficial. In chronic general anæmia, the usual treatment must be given, and as the general condition improves, the aural symptoms will gradually disappear and the hearing return to normal.

Lermoyez (*Ann. des malad. de l'oreille*, 1896) recommends the inhalation of several drops of amyl nitrite in those cases in which the labyrinthine symptoms are attributable to an anæmia of the internal ear. The diminution in the subjective noises, the subsidence of the dizziness, and the objective improvement in the hearing, render amyl nitrite in such cases of special value.

III. Hæmorrhages into the Labyrinth.

Small extravasations of blood into the labyrinth occur in consequence of a marked hyperæmia which develops rapidly; these are most commonly observed in the course of typhoid fever, variola, scarlet fever, diphtheria, mumps, nephritis, diabetes, leukæmia, pernicious anæmia, sudden cessation of menstruation, in caisson-workers and divers, and in death due to suffocation. The rupture of the bloodvessels is favoured by an atheromatous degeneration of the arteries, and by a chronic congestive hyperæmia associated with cardiac diseases. The finding of recent hæmorrhages in the labyrinth of animals which have been killed with chloroform is, according to Alexander's experiments, to be interpreted as agonal.
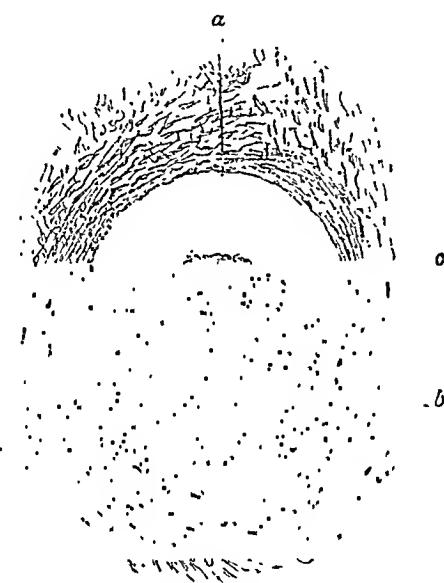
FIG. 285.

a, Section of the osseous semicircular canal; *b*, Extravasated blood; *c*, Section of the membranous semicircular canal.

Ecchymoses are most frequently observed in the lamina spiralis and modiolus, less often, however, in the saccule and utricle, and in the ampullæ. The extravasated blood may be absorbed, or the hæmoglobin may remain as granular or flaky pigment.

Larger effusions of blood into the labyrinth are found—(1) In injuries of the labyrinth due to fractures of the skull, and with fissures in the petrous bone. (2) In severe concussions of the skull. (3) In extensive carious processes in the temporal bone, especially in caries and necrosis of the petrous portion. In several cases in which the labyrinthine capsule remained uninjured, the author found different portions of the labyrinth—as,

for instance, the cochlea—covered with a blackish-brown, bloody extravasate. In a man who had died of meningitis secondary to otitis, and in whom the labyrinthine capsule was not eroded, the author found, on microscopic sections of the labyrinth, the bony (*a*) and membranous superior semicircular canal (*c*) (Fig. 285) and the ampullæ filled with a bloody extravasate (*b*), while the vestibule and cochlea were entirely free. (4) In diseases of the brain and its membranes, especially in primary and tubercular meningitis; in hæmorrhagic pachymeningitis; and furthermore in progressive paralysis (Moos and Steinbrügge, *Zeitsch. für Ohrenheilk.*, vol. ix.).

It remains to be seen from clinical and anatomical investigations whether hæmorrhages into the labyrinth can be produced by pathological changes in the vaso-motor centre. The experiments of Laborde and Duval (Baratoux, *Pathogénie des affections de l'oreille*, Paris, 1881) indicate the possibility of such occurrences; they found, on several occasions, that hæmorrhages into the cochlea took place when the medulla oblongata was punctured at certain parts.

Terminations.—The terminations of hæmorrhages into the labyrinth are: Absorption, inflammation which may end in suppuration, organization of the exudate, or, finally, atrophy and degeneration of the epithelium, of the connective tissue, and of the nerve elements, with the excessive formation of granular cells, hyaline bodies, and deposits of pigment.

According to Moos, the pigment metamorphosis of the extravasated blood in the labyrinth is sometimes extracellular and sometimes intracellular (owing to cells containing blood-corpuscles). The form and colour of the pigment present the same variations here as in other parts of the body. As a variable quantity of pigment is often found in the cochlea, even in the normal state, only large accumulations in the labyrinth can be regarded as pathological (Schwartze).

The Apoplectic Form of Menière's Disease.

Based on a number of cases observed clinically in which sudden deafness arose with apoplectic symptoms, accompanied by dizziness, vomiting, and subjective noises, Menière came to the conclusion that he was dealing in these cases with a peculiar affection of the labyrinth, in which, by an effusion of blood or by an acute exudation in the semicircular canals, a series of symptoms was produced similar to that which has been observed in animals after the semicircular canals have been injured.

The first case which had been carefully observed clinically, and in which a *post-mortem* examination was made, was published by Menière (*Gaz. méd. de Paris*, 1861); the patient was a young girl who, in consequence of a cold at the time of her catamenia, suddenly became deaf with symptoms of severe dizziness and vomiting, and died on the fifth day of the disease. The autopsy

revealed an unaltered state of the brain and spinal cord, but showed that the semicircular canals were filled with a reddish, plastic exudate which extended into the vestibule, while the cochlea was in a normal state.

Since the publication of Menière's paper, this affection, which is characterized by a distinct clinical picture, has been repeatedly observed and described. A distinction of this form of disease from other diseases of the ear and central nervous system, associated with a similar symptom-complex, seems justifiable from a clinical point of view.* Of the cases which have been thoroughly examined *post-mortem*, the following must be briefly mentioned:

A case recorded by the author (*Allg. Wien. med. Ztg.*, 1862) was that of a woman, fifty-six years of age, who, fourteen years previously, suddenly became deaf, with temporary unconsciousness, and with symptoms of the apoplectic form of Menière's disease. The *post-mortem* examination showed a bony growth on the external labyrinthine wall, the origin of which was probably due to an inflammation of the lining membrane of the labyrinth at that place. Among the cases of hæmorrhage in the labyrinth reported in literature, there is no other case, according to the author's knowledge, of the apoplectic form of deafness in an individual in whom the ears were previously normal. The finding of hæmorrhagic extravasates and leukæmic exudations in the labyrinth of leukæmic individuals who during their life showed labyrinthine symptoms is far more common (compare ' Leukæmic Deafness '). We must mention here the cases of Steinbrügge, Weber, Parkes, Lake, Lannois, Alexander, Koch (*Zeitschr. f. Ohrenheilk.*), Mott (*Med.-Surg. Transactions*, 1883), Alt and Pineles (*Infiltration of the Auditory Nerve*). F. Alexander and Manasse (*Zeitschr. f. Ohrenheilk.*, vol. lv.) found, in a case of progressive labyrinthine deafness which presented typical Menière's symptoms a short time before the patient's death, recent multiple hæmorrhages in the ramus cochlearis and vestibularis.

This affection usually attacks strong, robust individuals in the middle years of life whose power of hearing was previously normal. It seldom happens that tinnitus, slight attacks of dizziness, and a mild degree of deafness, have existed for a shorter or longer period before the attack presents itself. The following are considered the causes of this disease: intense heat, especially long exposure to the heat of the sun, rheumatic influences, influenza, lues, metalues, tabes dorsalis, leukæmia, nephritis, and pernicious anæmia. The cause of the affection often remains obscure.

Menière's disease presents itself either with symptoms of an apoplectic form of congestion of the brain, or in the form of a true apoplectic attack. It begins either with dizziness, tinnitus, nausea or vomiting, staggering gait, and marked deafness, or the individual falls suddenly with loss of consciousness as if struck down. Consciousness usually returns after a short time. The patient's face is pale and bathed in cold sweat, there is a

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* A complete and instructive account of this subject is found in Frankl-Hochwart's monograph, *Der Menière'sche Symptomencomplex*, in Nothnagel's *Spec. Pathologie u. Therapie*, Vienna, Hölder, second edition.

bilateral, more rarely a unilateral, hardness of hearing, or deafness accompanied by severe subjective noises, and as he tries to rise he has a feeling of nausea, vomiting, marked dizziness, and a staggering gait.* With every movement the dizziness and nausea increase.†

The examination of the ear usually shows a negative condition of the membrana tympani and of the Eustachian tube, and a minute investigation of the nervous system also demonstrates that there is no disturbance in the function of the cranial and spinal nerves.

The hearing is either completely destroyed or so diminished that only very loud noises in the immediate vicinity of the ear can be heard; the perception for the watch and acoumeter through the cranial bones is always absent. When the affection is bilateral, the tone of a vibrating tuning-fork placed on the vertex is not perceived at all or only indistinctly; in unilateral affections, however, the sound is always lateralized towards the normal ear. In total deafness, Rinne's test may be apparently negative.

Course.—The course of Menière's disease varies according to the intensity of the symptoms. Of the violent symptoms observed at the beginning of the attack, the unconsciousness and vomiting are the first to disappear, while the dizziness and disturbance of equilibrium, as a rule, diminish only in the course of several days to such an extent that the patient is able to walk a short distance with the aid of a cane. If there is a rotatory nystagmus to-wards the healthy side, it is usually noticed that, when the patient walks, there is a tendency to fall towards the affected side. The disturbances of equilibrium experienced in the dark, and while walking with closed eyes, are especially noticeable, inasmuch as even in those cases in which the affection is of a mild degree, the unsteadiness of gait may be as pronounced as that met with in the most severe forms of ataxia. The author can confirm, from his own experience, the observation of Guye that, in the beginning of the disease, the handwriting of the patient becomes completely altered, so that it resembles that of a tremulous old man. As the dizziness and unsteady gait decrease, the handwriting gradually regains its former character. In addition to the symptoms previously mentioned, it is found that in the first few weeks of this apoplectic form of deafness, psychical depression, slow cerebration, and weakness of memory also develop, so that

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* The oppression and asphyxia, as well as the vomiting, are attributed by Moos and McBride to a reflex action of the vagus. Hughlings-Jackson attributes the marked paleness, cold perspiration, fainting spells, and vomiting to the intimate relations of the acoustic nucleus to those of the vagus and accessory nerves.

† Cp. Urban Pritchard, *Menière's Disease* (Internat. Med. Congress in Paris, 1900).

the neurasthenic condition which, in some patients arises during the course of the disease, plays an important part.

In those patients in whom no relapse takes place after the first attack, the dizziness and disturbances of equilibrium gradually decrease, and disappear entirely within a few weeks or months. The unsteadiness in the gait may, however, continue for years. The marked buzzing and hissing in the ears and head diminish in their intensity in the later course of the disease, but may continue unabated, even with total deafness, throughout the entire life of the patient. The loss of hearing usually remains stationary; it is only in exceptional cases that a slight improvement is observed, which is either permanent or gradually becomes worse after months or years. Occasionally the affection runs its course without any relapse. Still, the author has repeatedly seen patients in whom new attacks of dizziness and vomiting, with a simultaneous increase in the other symptoms, have reappeared even after weeks, months, or years.

Diagnosis.—The diagnosis of the apoplectic form of Menière's disease is made from the combination of symptoms already mentioned, and from the absence of symptoms of paralysis of any of the other cranial and spinal nerves. The assumption that we are dealing with an affection of the brain in these cases is, according to Menière, out of the question, because symptoms of paralysis are observed in no other organ except the auditory nerve apparatus. This would not be possible, however, if the nuclei of the acoustic nerve were affected, inasmuch as the centres of other cranial nerves lying in the immediate vicinity would also become involved in the pathological process. In those cases in which it is found that tinnitus, a feeling of pressure and fulness in the ear, repeated attacks of dizziness and stupor, or a mild degree of deafness, have existed for some time previous to the attack, the diagnosis of Menière's disease must not be made without some further evidence. This is easily understood, as it has been previously stated that attacks of dizziness associated with ringing in the ears and vomiting and sudden deafness not infrequently also occur in diseases of the middle ear and of the brain. If Menière's disease occurs in individuals who are the subjects of nephritis, lues, leukæmia, or pernicious anæmia, and in whom it is known that there is a predisposition to hæmorrhages, it may be assumed with probability that a hæmorrhage or exudation has taken place into the labyrinth, provided an affection of the central nervous system can be excluded.

Facial paralysis arising simultaneously with Menière's symptoms, and in which a middle-ear affection can be excluded, may, on the other hand, be regarded as due only to some central changes. V. Frankl-Hochwart observed, in cases of apoplectic form of Menière's disease, a simultaneous total paralysis of the facial nerve, and attributed this entire combination of symptoms to a hæmorrhage at the base of the brain.

Somewhat different from this is a condition described by V. Frankl-Hochwart, as ' polyneuritis cerebralis Menieriformis,' in which there are nerve deafness, tinnitus aurium, and dizziness, associated with a facial paralysis and herpes. Characteristic of this form of disease is its sudden appearance and its rapid recovery.

The diagnosis of Mènière's disease may be made with certainty only if the affection comes on with marked symptoms without any premonitory phenomena, and if the ear is examined shortly after the attack. If, therefore, a marked impairment in the hearing or deafness arises suddenly with symptoms of an apoplectic attack in a person whose hearing power was previously entirely normal, if the gait is unsteady or staggering with no other symptoms of paralysis of other nerves, and if an examination made a short time after the attack shows a normal membrane and a perfectly permeable Eustachian tube, it may then be assumed with great probability that we are dealing with an affection of the labyrinth; it cannot be mistaken for an acute middle-ear affection, because this is always characterized by noticeable inflammatory changes on the membrana tympani.

Prognosis.—The prognosis of the apoplectic form of Menière's disease is unfavourable; a cure or a decided improvement in the hearing has rarely been obtained. When the affection has existed only a short time and the hearing is not greatly reduced, the possibility of an improvement must not be excluded. When total deafness has existed for months or years, the prognosis is absolutely unfavourable. The dizziness generally disappears gradually, even if it has existed for years.

Treatment.—The same applies in general to the treatment of Menière's disease and the combination of symptoms resembling this affection, as has already been mentioned under the treatment of hyperæmia and anæmia of the internal ear. In the apoplectic form, as well as in Menière's symptoms, which occur in paroxysms, the treatment is mainly directed to the troublesome head symptoms. Cold compresses to the head, alcoholic embrocations behind the ears, sinapisms on the nape of the neck, frequently sponging the body, and the administration of mild purgatives, prove most beneficial in alleviating the violent symptoms. The diet must be carefully regulated, and the use of alcohol, tea, and coffee forbidden. It is also advisable to make the patient lie on his back with the head moderately raised, as even the slightest motion or raising of the body is sufficient to bring on marked attacks of dizziness and vomiting. Loud noises and psychical depression are to be avoided.

The internal administration of potassium iodide has proved most serviceable in relieving the dizziness and the other head symptoms. It is given in doses of $\frac{1}{2}$–1 gramme per day for at least three to four weeks. Quinine ($\frac{1}{2}$–1 gramme pro die), as

recommended by Charcot, has proved of value, but must, however, be carefully watched in each case, as sometimes even moderate doses may produce the opposite effect—that is, great excitement and increased tinnitus. Lucae (*loc. cit.*) recommends isopral (0·5 gramme pro die) as an excellent drug for the dizziness in cases of sclerosis and labyrinthine affections. The bromide preparations may be given for the nervous irritability. In the apoplectic form, after the violent symptoms have subsided, subcutaneous injections of pilocarpin in 2 per cent. solutions (4–10 drops pro die), or the internal administration of 4–8 drops of the same, is recommended in the second or third week of the attack to aid absorption.

Little may be expected from local treatment in the apoplectic form of this affection. It should be begun only after the violent head symptoms have ceased—that is, in about the second or third week of the attack. It consists in the injection of ·8–10 drops of a warm solution of potassium iodide (0·3 : 20·0), or a 2 per cent. solution of pilocarpin, through the catheter into the tympanic cavity. The injections are given every second day for three to four weeks; in addition to these, inunctions of a potassium iodide or an iodide salve (1 : 20) may be applied to the mastoid process.

The electric treatment (*vide later*) is contra-indicated in the beginning of the affection, because it increases the dizziness and tinnitus; even after the disappearance of the disturbance of equilibrium only weak currents should be employed. According to v. Frankl-Hochwart, one electrode is placed against each mastoid process, and by carefully opening and closing the circuit weak currents are used (not over 1·5 ma.); these are at first applied from two to three, later from five to seven minutes. In the beginning of treatment these electric applications should be given daily, later three times a week. Franklin's head-douche is sometimes serviceable instead of the galvanic treatment. If, after fifteen to twenty sittings, no improvement is noticed from this method of treatment, further attempts must be discontinued. In some cases drinking waters which contain salts or iodides, and bathing in the same, and a sojourn in a high altitude, have proved beneficial. It must, however, be remarked that although no improvement is effected in the hearing, still in some cases this method of treatment has a favourable influence on the head symptoms and on the mental condition of the patient.

The symptomatic treatment detailed above can also be employed in Menière's symptoms accompanying affections of the middle ear and labyrinth. Rarefaction of the air in the external meatus (p. 135) is an important therapeutic measure, not only in middle-ear diseases, but also in affections of the labyrinth, inasmuch as it often prevents or decidedly diminishes the attack. Rarefaction of the air proves especially beneficial in those cases

in which the attack is preceded by premonitory symptoms. It is, therefore, recommended to allow the patient, in whom Menière's symptoms appear in paroxysms, to carry with him a rubber tube ⅓ metre long, the one end of which can be hermetically introduced into the external meatus; when the patient has the sensation of an approaching attack, he can take the other end of the tube in his mouth, and by repeatedly aspirating he can rarefy the air in the external meatus.

In cases of Menière's disease associated with chronic catarrhs of the middle ear in which there is an impermeability of the Eustachian tube, local treatment [inflations of air, catheterization of the tube, and injections into the tympanic cavity (p. 122)] is often very serviceable. If the membrana tympani is markedly retracted, or if there are cicatricial adhesions between the membrane and inner tympanic wall—conditions which would allow us to assume that there is an overweighting of the stapes and an increase in the labyrinthine pressure—we should resort, after local and general treatment has failed, to division of the posterior fold of the membrane (p. 321), or of the adhesions of the membrane (p. 448), and eventually to tenotomy of the tendon of the tensor tympani muscle (p. 323); by these operative procedures it is occasionally possible to relieve the patient of his annoying symptoms. Babinski reports favourable results from repeated lumbar puncture in cases in which there were dizziness, subjective noises, and hardness of hearing. Trétrôp, Lombard, and Caboche (*Ann. des mal. de l'oreille*, vol. xxx.), confirm the experiences of Babinski, especially in patients who suffer at the same time from disorders of congestion.

IV. Inflammation of the Labyrinth.

(Otitis interna.)

Clinical observations of primary inflammation of the labyrinth with *post-mortem* findings are, up to the present, few in number.

Voltolini has drawn the attention of otologists to an affection of the ear occurring in children which he designates as acute inflammation of the labyrinth. In children who are apparently in good health, the disease arises suddenly with fever, marked redness of the face, and vomiting, which are soon followed by unconsciousness, delirium, and convulsions. These symptoms disappear completely within a few days, but total deafness and a staggering gait remain for some time. The phenomena observed during the height of the disease present a great similarity to those of an acute meningeal affection. While, however, a meningitis ending in deafness generally runs its course within several weeks, the grave symptoms of this affection disappear within a short time, so that very often all the functions are restored to their normal state within four to five days, with the exception of the deafness and staggering gait. The difference in time in which the symptoms run their course is the main factor upon which the diagnosis of primary inflammation of the labyrinth is based.

The conclusion that an intracranial affection which leads to total paralysis of the acoustic nerve within a few days must necessarily also produce disturbances in the course of other cranial nerves, and that, therefore, a central

cause of the deafness in these cases may be excluded, does not seem sufficient evidence to allow us to establish with absolute certainty the diagnosis of an acute inflammation of the labyrinth. The observations of Gottstein show that abortive forms presenting a similar combination of symptoms occur during epidemics of cerebro-spinal meningitis, and that the initial symptoms subside within a few days either with complete recovery or with a permanent loss of the hearing. The latter may be caused either by a simultaneous purulent inflammation of the labyrinth which has extended from the cranial cavity, or by an affection of the origin or root of the acoustic nerve. The absence in these cases of simultaneous disturbances in the other cranial nerves may be explained by the fact that the auditory nerve may be permanently altered even by the slightest pathological change, while the other cranial nerves possess a greater power of resistance.

The occurrence in children of a primary inflammation of the labyrinth, accompanied by the combination of symptoms previously described, has been firmly established by clinical observations and by *post-mortem* findings. The results of these investigations have shown that inflammations of the labyrinth resulting in the new formation of connective tissue and bone occur more frequently than was formerly supposed.

Partial or total ossification of the internal ear owing to an inflammation of the labyrinth has been observed a number of times. In a case of deaf-mutism examined by Gradenigo (*Vereinig. süddeutscher u. schweizerischer Ohrenärzte in Wien*, 1887) an almost complete ossification of the labyrinth was found. Serial microscopic sections which came into the author's possession by the bequest of his deceased friend, Professor Burckhardt-Merian, were taken from a deaf-mute thirty-six years of age. Examination showed that the greater part of the first turn of the cochlea was completely ossified, while the middle and upper turns were not affected. The spiral ganglion still contained a number of ganglion cells. It must be mentioned, however, that in the cases of partial ossification of the labyrinth published so far, the new formation of bone was most highly developed in the first turn of the cochlea, and gradually became less towards the cupola.

Of the pathological changes in the interior of the labyrinth produced by the primary and secondary inflammations of the labyrinth, the following must be mentioned: New formation of connective tissue; chalk deposits and hyperostoses in the walls of the labyrinth; the growth of reddish, succulent, connective-tissue masses filling the labyrinthine cavity; transformation of the connective tissue into bony masses (Politzer, Moos, Steinbrügge, F. Schultze); thickening of the utricle, saccule, ampullæ, and semicircular canals (Voltolini, *Virch. Arch.*, vol. xxii.); deposits of pigment, cholesterin, and calcium salts in the membranous labyrinth; excessive growth of epithelium on the inner surfaces of the saccule, utricle, and scalæ of the cochlea (Politzer); atrophy of the membranous labyrinth; and, finally, fatty degeneration and atrophy of the organ of Corti. That an exudation may also take place into the labyrinth owing to an obstruction in the venous circulation is proved by the following case which came under the author's notice: The patient was a man, sixty-three years of age, in whom a sarcoma of the dura mater completely compressed the nerves and vessels of the internal auditory meatus. A plastic, fibrinous deposit about $\frac{1}{3}$ mm. in thickness was found on the inner surfaces of the saccule and utricle, in the cochlea, and in the semicircular canals. The *post-mortem* examinations made by the author show that pathological changes (exudation, formation of connective tissue and bone) occur most frequently in the scala tympani of the cochlea. According to Steinbrügge, the first turn of the cochlea is that part of the labyrinth which undergoes the most intense changes.

Blau (Görlitz, *Verh. d. Deutsch. otol. Ges.*, Wien, 1906) found, by experiments on animals, that there was absolutely no reaction to tones and noises after closure of the fenestra rotunda. This closure is followed by an increased labyrinthine pressure and an inflammatory coagulation of the labyrinthine fluid, which lead to the new formation of connective tissue and bone, and to degenerative changes in the cochlear nerve. The labyrinthine inflammations induced by the purulent middle-ear processes were already discussed in the chapter on Labyrinthine Suppurations.

The disturbances of hearing which are the sequelæ of meningitis purulenta or of meningitis cerebro-spinalis epidemica are due to secondary inflammations of the labyrinth. They are, on the whole, seldom found after a primary meningitis which has run its course. The deafness in these cases is due to a purulent inflammation of the ependyma and softening of the floor of the fourth ventricle, to purulent infiltration, fatty degeneration and atrophy of the root of the acoustic nerve, and to purulent inflammation of the labyrinth with its various sequelæ.

The deafness arising in the course of the primary form of meningitis becomes evident either immediately after the return of consciousness, between the third and eighth week of the disease, or it develops more or less rapidly only during convalescence. It is only in exceptional cases that the disturbance of hearing is associated with unilateral or bilateral blindness, strabismus, and paralysis of other nerves. Children, as a rule, become totally deaf and show a staggering, uncertain gait which lasts for some months. In adults, on the other hand, there is rarely total deafness, but in place of this subjective noises and disturbances of hearing of varying intensity often remain, which hardly ever disappear entirely. Occasionally a decided improvement is observed after convalescence, which, however, gradually becomes lost again after months or years. Moos reports disturbances in hearing in pachymeningitis hæmorrhagica, which are brought about by a hæmorrhagic exudation into the labyrinth.

Disturbances of hearing are much more often observed as the sequelæ of epidemic cerebro-spinal meningitis, which occurs most frequently in children.

The anatomical changes which give rise to disturbances of hearing in this form of disease are: Softening or thickening of the ependyma of the fourth ventricle, purulent infiltration and degeneration of the acoustic nerve, embedding of the same in the meningeal exudate, atrophy of the root of the nerve, and purulent inflammation of the membranous labyrinth. The last of these conditions is due to the entrance of the purulent meningeal exudate by way of the aquæductus cochleæ into the labyrinth. The direct action of the bacteria (meningococcus, *Diplococcus pneumoniæ*—Weichselbaum, Bordone-Uffreduzzi) upon the bloodvessels of the labyrinth leads to necrosis of the structures of the internal ear, and to inflammatory connective tissue and bone formation, with partial obliteration of the labyrinthine cavity.

In cerebro-spinal meningitis a vast number of pathological conditions in the labyrinth have been found. Heller (*Deutsch. Arch. f. klin. Med.*, vol. iii.) observed in a man forty-two years of age, who had died of cerebro-spinal meningitis, both tympanic cavities and vestibules filled with pus. In a woman forty-five years of age, who had also died of purulent cerebro-spinal meningitis, the same author found numerous punctate ecchymoses in the lamina spiralis which had been infiltrated with pus. The acoustic nerves were also infiltrated with pus cells. Lucae (*A. f. O.*, vol. v.) observed a purulent inflammation of the acoustic nerve, saccule, utricle, ampullæ, and semicircular canals in a man forty years of age. In a case of cerebro-spinal meningitis which had relapsed, and in which complete deafness had already taken place during the first attack, Habermann (*Zeitschr. f. Heilk.*, vol. iii., 1886) found the structures of the internal ear completely destroyed and replaced by the growth of granulation tissue, a purulent infiltration of the ramus cochlearis and vestibularis, and a filling up of the aquæductus cochleæ with granulation tissue. Schwabach (*Zeitschr. f. klin. Med.*, vol. xviii.) found a purulent perineuritis of the acoustic nerve, and a hæmorrhagic and purulent inflammation associated with the formation of granulations in the scala tympani of the cochlea, and in the lining membrane of the vestibule. Alt found, after the affection had lasted nine days, a purulent inflammation of the labyrinth, and a purulent infiltration of the ramus cochleæ and of the ganglion spirale. From the numerous specimens examined *post-mortem*, we know that inflammation of the labyrinth brought about by epidemic cerebro-spinal meningitis terminates in the new formation of connective tissue and bone. Such changes have been observed by Schultze (*Virch. Arch.*, vol. cxix., bk. i.) in a congenital-deaf and dumb child who died five years after this affection of the brain; by Moos (*Z. f. O.*, vol. xii.) in a girl who had become deaf and dumb after meningitis; by Larsen and Mygind (*A. f. O.*, vol. xxx.) in a man who became deaf and dumb from an attack of cerebro-spinal meningitis, and who died at the age of twenty-seven from tuberculosis; and by Sehcibe (*Z. f. O.*, 1895) in a boy who four years previously became deaf owing to cerebro-spinal meningitis. Baginsky (*Arch. f. Kinderh.*, 1900) found sclerosing ostitis of the petrous bone and degeneration of the auditory nerve in a girl thirteen years of age, who three months previously became deaf from an affection presenting the symptoms of cerebro-spinal meningitis. Alt saw, in a case in which the affection had existed fifty-nine days, a new formation of connective tissue and bone nearly filling the entire interior of the labyrinth, in addition to slight purulent infiltration; and in another case of sixty-one days' duration a partial new formation of connective tissue and bone, and a complete destruction of the auditory nerve apparatus. Goerke (*Deutsch. Otologent.*, 1906) found that infection took place by way of the aquæductus cochleæ in three cases, through the aquæductus vestibuli in one case, and in eleven cases the infection spread along the auditory nerve through the internal meatus. In the majority of cases belonging to this category, degenerative changes have been observed in the acoustic nerve and in the organ of Corti.

Epidemic cerebro-spinal meningitis develops with the symptoms of an ordinary meningitis—that is, with headache, fever, vomiting, loss of consciousness, and occasionally convulsions.

In the majority of cases, the disturbances of hearing brought about by this disease develop, according to Moos and Knapp, in the first or second week of the attack, rarely later. The intensity of the general disease seems to have less influence on the development of the deafness than its epidemic character. While very severe cases often recover without disturbances of hearing, complete deafness frequently develops in the abortive forms of this affection. Gottstein observed during an epidemic, complete

deafness in patients who complained of exhaustion, headache, and rigidity of the neck for a number of days, and also in those who were able to leave their beds even in two to three days after the violent symptoms (fever, vomiting, convulsions, loss of consciousness, contraction of the muscles of the neck) had passed away. From information obtained by the author from physicians who had the opportunity of observing severe epidemics, it was seen that in some epidemics only a few individuals lose their power of hearing, while in others, the majority of those who do not succumb to the affection become deaf.

Deafness, which remains after an epidemic cerebro-spinal meningitis, affects both ears in the great majority of cases. When the two organs are unequally affected, the one ear, as a rule, becomes totally deaf, while the other loses its hearing power to a marked degree. According to Kirchner, even in those cases in which there is total deafness for speech and tones, some scraping and creaking noises may still be very distinctly perceived.

The most noticeable symptom accompanying the deafness after cerebro-spinal meningitis, is the staggering gait (waddling gait of a duck). Moos found disturbances of equilibrium in half of the cases observed by him; according to the author's records, they were present in more than two-thirds of the cases. The staggering, uncertain gait lasts all the longer the younger the individual is at the time of the affection. As a rule, these disturbances of equilibrium gradually disappear after several months, but in exceptional cases only after a year, and more rapidly in older persons than in children (Alt). Whether these disturbances in equilibrium are brought about by a bilateral destruction of the vestibular apparatus, as is assumed by Alt, or, as Bárány believes, by a simultaneous affection of the cerebellar fibres, has not as yet been established.

Subjective noises are frequently met with in adults, but seem to be less troublesome in children, who, on the whole, seldom complain of tinnitus.

In exceptional cases the deafness is associated with unilateral or bilateral disturbance of vision or blindness, with disturbances of speech, and with paralysis of other nerves. The disturbances of vision, just as the disturbances of hearing, may disappear.

Diagnosis.—The diagnosis is made from the characteristic symptom-complex. It is furthermore substantiated by the result of the lumbar puncture, which should be performed in the earliest stage of the affection (meningococci, Weichselbaum).

Prognosis.—The prognosis is, on the whole, unfavourable. A complete return to the normal is a rare occurrence: Moos correctly remarks, however, that the percentage of cured and improved cases is higher in the experience of the general practitioner who observes the cases during an epidemic, than in the experience of the specialist to whom the afflicted individuals are

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brought some weeks or months after the outbreak of the disease. Cases of deafness are but seldom met with in which the power of hearing in one ear, rarely in both, undergoes such an improvement during convalescence or later that speech can be understood even at a short distance. According to Moos, the development of subjective sensations of sound and the increased perception for musical tones during convalescence may be regarded as favourable prognostic signs for the restoration of the hearing. The return of the hearing power for speech is not always permanent, as the author's experience has shown that complete deafness may return again at a later date.

Treatment.—The treatment is almost always unsuccessful. In those cases of meningitis in which the aural symptoms become apparent, cold applications in the form of ice-bags should be applied to the region of the ear and mastoid process. If the case comes under treatment shortly after the meningitis has run its course, the main object is to bring about an absorption of the exudate which may possibly not yet have become organized. It is, therefore, advisable to give potassium iodide (0·5–2·0 grammes daily); or ammonium iodide (ammonium iodide 5·0 grammes, mistura gummosa 100·0 grammes, syrupus corticis aurantii 15·0 grammes; 1 tablespoonful three times a day); or pilocarpin muriate (4–6 drops of a 2 per cent. solution internally, or 2–4 drops injected subcutaneously); furthermore, it is well to apply an iodide, iodoform or iodol salve to the mastoid process, and when circumstances permit, the patients are urged to spend some weeks at a resort where they can drink the waters containing the iodides, and also take the baths. The internal and external use of strychnin. nitr. never yields any favourable result; the same may be said of electricity, which Moos applies only in those cases in which a certain degree of hearing power is still preserved.

Panotitis.

The author applies this term to a form of disease of the organ of hearing in which the middle ear and labyrinth become affected by the inflammation either simultaneously or in rapid succession.

It occurs chiefly in children, either as a primary affection, or in the course of scarlatinal diphtheria, and always affects both ears, leading, after a strikingly short duration, to total deafness.

The primary form begins with high fever, which is often accompanied by eclamptic seizures, with or without loss of consciousness. The duration of these attacks varies from a few hours to several days. After the return of consciousness, the individual is found to be totally deaf, and there is a discharge from both ears, with perforation of the tympanic membranes. In all cases thus far reported the affection was associated with a staggering, uncertain gait.

This form of disease, just described, may be illustrated by a few cases.

The first case was that of a boy, who at the age of two and a half years, according to his father, became deaf during a febrile disease which lasted fourteen days and was accompanied by eclamptic attacks and a discharge from both ears. The otorrhœa is supposed to have lasted until the age of six or seven.

His death was caused by an acute peritonitis in his thirteenth year. The autopsy revealed the following: Both tympanic membranes, as well as the mucous membrane of the tympanic cavities, were normal, and the malleus and incus were movable. The stapes was fixed and immovable on both sides; the recess of the round window was indicated by a small depression, the floor of which was formed by a solid, osseous mass.

Histological Examination (Fig. 286).—The cavity of the cochlea (b) was completely filled with newly-formed bony tissue, which had the character of a very vascular periosteum. The turns of the cochlea could be distinctly discerned throughout their entire extent; the capsule of the cochlea was sharply defined from the underlying surface of the petrous bone. The auditory nerve
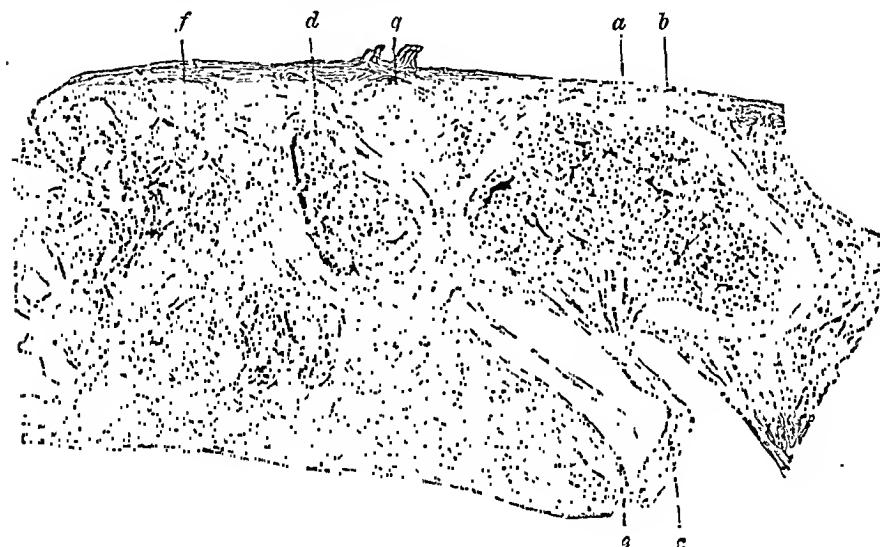
Fig. 286.

(c) entered the modiolus with its medullated fibres normally arranged, and unchanged by fatty degeneration; these fibres, however, could be traced into the newly-formed bony mass only for a short distance.

The vestibule (d) was narrowed by the hyperplastic process to a narrow angular cleft which was lined with round-celled epithelium. The semicircular canals (f) were entirely absent. It was only with a higher magnifying power that the corresponding places were recognizable, owing to the peculiar structure of the newly-formed bone which completely filled the canals. There is no doubt that in this case the filling of the labyrinthine cavity with new bony tissue was the result of an inflammatory process.

In a child six years of age the affection began with high fever, followed in the course of several hours by an eclamptic seizure without loss of consciousness. Sudden deafness developed after thirty-six hours. On the tenth day after the fever remitted there was a discharge from both ears, which ceased after fourteen days. Four days later an abscess formed behind the right ear, which was opened, and healed after a short time. Five months after the commencement of the affection the examination of the right ear showed a dry perforation behind the handle of the malleus; in the left ear a cicatrix in

the membrane which was found in the same situation as in the right ear, and which had become adherent to the inner tympanic wall. The hearing for every kind of tone and noise was completely lost.

In a boy three years old, high fever and headache developed without loss of consciousness. After two days a slight discharge was noticed from both ears with an abatement of the fever. The parents noticed at the same time that the child had become totally deaf, and that it staggered so markedly in walking that it fell after taking a few steps. The objective examination showed perforation of both tympanic membranes, and the tuning-fork tests revealed a total deafness.

There is no doubt that in these cases the middle ear and the labyrinth had been affected by the inflammatory process. Whether, however, the process arose in both parts of the ear simultaneously, or whether it affected the one before the other, could not be determined, as the cases were not observed from the beginning of the attack. The late appearance of the discharge in the second case—ten days after the commencement of the affection—would indicate that the suppuration might possibly have originated in the labyrinth, and that it extended to the middle ear after perforating the round and oval windows.

Prognosis.—The prognosis of this form of inflammation is unfavourable.

Treatment.—The treatment of panotitis consists in the internal administration of sodium or potassium iodide, long-continued inunctions of iodide and iodoform salves behind the ear, and the subcutaneous injections of a 2 per cent. solution of muriate of pilocarpin (2–4 drops for twenty to thirty days); all these remedies however, are ineffectual in the majority of cases.

To the diphtheritic form of panotitis one must add those cases in which total deafness arises during the course of scarlatinal diphtheria. The loss of hearing is brought about either by a purulent inflammation of the membranous structures of the internal ear, or by the invasion of micrococci into the labyrinth, which leads to a disorganization of the terminal filaments of the acoustic nerve.

The prognosis of panotitis diphtheritica is not absolutely unfavourable, as has been shown by the cases observed by Moos, O. Wolf, and others, in which the pilocarpin treatment was used. In a few cases the muriate of pilocarpin, first recommended by the author for the absorption of labyrinthine exudates, has proved to be of some value. The results are on the whole unsatisfactory, but one should nevertheless try this drug in every case in which there is a sudden loss of hearing of labyrinthine origin.

V. Leukæmic Deafness.

During the course of leukæmia exudative and hæmorrhagic processes are found in the ear, as well as in other organs of the body (liver, kidney, lymph-glands, serous and mucous mem-

branes); such changes are generally observed in the labyrinth, less often in the middle ear. Disturbances of hearing arising in the course of a leukæmia are far less often observed than leukæmic retinitis; Vidal and Isambert, however, have found that disturbances of hearing occur in about 10 per cent. of all cases of leukæmia. The affection, which usually arises during the middle years of life, is more often met with in males than in females. The first case of leukæmic deafness which had been clinically observed and pathologically examined was reported by the author at the Otological Congress in Basel in the year 1885:

A man thirty-two years of age, who had been afflicted with a severe form of splenic, glandular, and myelogenic leukæmia, and who had suffered from an otorrhœa in his left ear for a long time while a boy, suddenly became
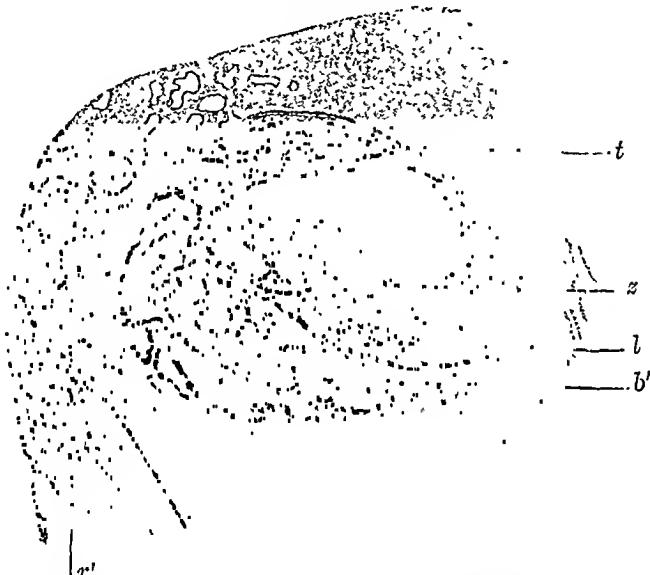
FIG. 287.—SECTION OF THE FIRST TURN OF COCHLEA FROM A DEAF MAN, AGED 32, WHO DIED OF LEUKÆMIA.

l, Lamina spiralis; *b'*, Connective tissue and osseous growth in the scala tympani; *z*, Leukæmic plaques in the scala vestibuli; *t*, Osseous growth on the median wall of the scala vestibuli; *r'*, Atrophic ganglion layer in canalis ganglionaris.

totally deaf in both ears overnight about one year before his death. The objective examination of his ears two months prior to his death showed: Cloudiness and retraction of the right, and almost total destruction of the left, membrana tympani, causing complete bilateral deafness. The diagnosis of leukæmic exudation into the labyrinth was made. The *post-mortem* examination showed in the right ear, besides the characteristic conditions of leukæmia, marked retraction of the membrane tympani and great thickening of the mucous membrane of the middle ear and of the covering of the ossicular articulations;- in the left ear, total absence of the membrana tympani, hammer and incus, swelling and thickening of the mucous membrane of the tympanic cavity.

The histological examination of the internal ear confirmed the clinical diagnosis. In sections of the cochlea (Fig. 287) the scala tympani was found infiltrated with an irregularly formed, osseous framework (*b'*) which was attached to the bony wall of the cochlea, the scalæ of which contained newly-

formed connective tissue in the various stages of development. In the scala vestibuli there were, in addition to a large osseous growth (*t*), leukæmic plaques (*z*) consisting of lymph-cells and resting on the medial wall of the cochlea and on the lamina spiralis (*l*). The membranous semicircular canals were surrounded by connective tissue which was rich in young cells and bloodvessels, and which completely filled the space between the membranous and osseous semicircular canals. The space within the membranous semicircular canals was filled with leukæmic lymph-cells. Similar accumulations of lymph-cells were found in all parts of the vestibule of the right ear, and also in the labyrinth of the left side, where only traces of new connective tissue were present. Since the publication of this case, the pathology of leukæmic deafness has been greatly enriched by a number of interesting conditions found at the *post-mortem* examination.

In a case observed by Steinbrügge (*Z. f. O.*, vol. xvi.) of a leukæmic individual, twenty-five years of age, in whom deafness suddenly occurred in the right ear fourteen days prior to death, the *post-mortem* examination revealed the following: Old connective-tissue adhesions in the recesses of the windows, a marked extravasation of blood in the cochlea, which covered the organ of Corti, and an abundant exudate in the saccule. In a case (man, thirty-four years of age) of leukæmia, which had been carefully observed and minutely examined histologically by Lannois (Gouguenheim's *Annales des maladies de l'oreille*, etc., 1892), total deafness accompanied by Menière's symptoms developed eight months before the fatal termination. The histological examination showed bloody extravasations in the vestibule and semicircular canals, masses of fibrin in the process of organization, newly-formed connective tissue in the osseous semicircular canals, and cell infiltration in the scala vestibuli of the first turn of the cochlea.

Wagenhäuser reported the case of a woman, thirty-five years of age, who had suffered from splenic leukæmia. In this case extravasations were discovered in the cochlea and vestibule, and newly-formed connective tissue and bony growths arising from the periosteum were also seen scattered here and there in the ampullæ and semicircular canals (*A. f. O.*, vol. xxxiv.). There is also another case reported by Weber, H. Parkes, and Lake (*Proceedings of the Royal Medical and Surgical Society*, 1900), in which there were new formations of fibrinous and bony tissue in the scala tympani and in the perilymphatic spaces of the semicircular canals; the patient was a man affected with splenic medullary leukæmia, who was taken ill six months before his death with symptoms of Menière's disease. Finlayson (*Brit. Med. Journal*, 1890) reported a case in which there were hæmorrhagic deposits in the vestibule and cochlea in a woman, twenty-five years of age, who had been seized with Menière's symptoms, and who became very deaf in both ears. Schwabach (*Z. f. O.*, vol. xxxi.) found a leukæmic infiltrate and hæmorrhages in the labyrinth; Alt and Pineles (*Wiener klin. Wochenschr.*, 1896) observed leukæmic infiltration of the acoustic nucleus. Gradenigo (*A. f. O.*, vol. xxiii.) found in a man with marked leukæmia and disturbances of hearing in both ears only an extensive development of the mucous membrane of the middle ear with parenchymatous hæmorrhages, but no changes, however, in the labyrinth.

The lymphomatous affections of the organ of hearing have been examined anatomically and clinically by Alexander (*Zeitschr. f. Ohrenheilk.*, 1906). The anatomical changes observed by Alexander were hæmorrhages into the labyrinth with partial or total compression of the membranous labyrinth, and a lymphoid infiltrate in the sheaths of the acoustic nerve and in the nerve-endings in the labyrinth; furthermore, a hæmorrhagic and lymphoid infiltration of the ganglion, of the proximal portion, and of the root of the acoustic nerve, and degenerative changes in the acoustic nerve itself or in its central part, and in the region of the cortex of the brain; these were manifest as subpial hæmorrhages in all the roots of the cranial nerves, which took their origin from a hæmorrhage which extended from the angle of the peduncle of the cerebellum into the cerebellum itself. In a case of chloroma, Alexander found masses of

growths in the labyrinth, and multiple hæmorrhages which caused a decided ectasis of the inferior part of the labyrinth. In a case of acute lymphoid leukæmia with a lympho-sarcoma, and in a case of chronic lymphoid leukæmia, otosclerotic changes were observed in the labyrinthine capsule, which corresponded microscopically precisely with bony changes found by the author in otosclerosis. The leukæmic hæmorrhages generally take place in the semi-circular canals and in the ampullæ. The chronic cases show the new formation of connective tissue with partial obliteration of the membranous labyrinth, extensive degenerative changes in the nerve-endings, and pigmentation.

In thirty-one patients afflicted with lymphomata, Alexander found the following forms of lymphoid aural affections: (1) Acute exudative middle-ear catarrh. (2) Acute and subacute tubal catarrh, with the eventual development of lymphoid tumours in the tube (in cases of lympho-sarcoma or chloroma). (3) Acute hæmorrhagic (purulent) middle-ear inflammation. (4) Acute hæmorrhagic mastoiditis. (5) Acute hæmorrhagic panotitis (Politzer). (6) Acute labyrinthitis. (7) Acute neuritis acustica leukæmica. (8) Hæmorrhages into the meatus. (9) Hæmorrhages into the middle ear. (10) Hæmorrhages into the labyrinth.

Leukæmic affection of the labyrinth either begins suddenly with total deafness, dizziness, and marked Menière's symptoms, or it appears with moderate loss of hearing, which rapidly gets worse and leads to total deafness within a few weeks or months. Schwabach states that, in the acute forms of leukæmia the disturbances of hearing arise in the initial stage of the affection, while in the chronic cases, they appear in the later stage. When the hearing improves, or becomes normal during the course of a leukæmic affection of the ear, it may be assumed that we have to do either with a catarrhal disease of the middle ear, or with only slight changes in the labyrinth. In the severer forms, in consequence of a leukæmic exudation (accumulations of lymphocytes and hæmorrhages) into the labyrinth, there is a reactive inflammation of the endosteum and membranous labyrinth, which leads to connective-tissue obliteration and partial ossification of the labyrinth. The prognosis of a true leukæmic deafness is unfavourable.

VI. Syphilis of the Internal Ear.

Syphilis of the labyrinth seldom develops simultaneously with the secondary lesions of the skin or throat. The author once observed this on the seventh day after the primary lesion. It more often appears as a later form of syphilis, generally at the end of the secondary or at the beginning of the tertiary stage, or it becomes evident only after one to two years, or even later, either with a new outbreak of syphilitic symptoms (in one of the author's cases with a gumma on the head twenty-one years later), or without the least trace of a general syphilitic infection. Labyrinthine syphilis may occur as the only symptom of a general infection which has not yet entirely disappeared, and may either be localized in the internal ear, or may appear simultaneously with a catarrhal or purulent middle-ear inflammation. In like

manner syphilitic affection of the labyrinth may arise in the course of a middle-ear disorder which has existed before infection has taken place. It has been stated that the frequency of syphilis of the labyrinth varies from 7–48 per cent. (Schwabach, Kretschmann, Wiese).

The anatomical changes in syphilis of the labyrinth are but little known. Whether, in the recent cases, there is a plastic exudation into the labyrinth similar to that found in syphilitic iritis has not been proved. There is also little known of the inveterate forms. Toynbee found thickening of the periosteum of the vestibule in one case. Moos (*Virch. Arch.*, vol. lx., p. 313) reported the case of a syphilitic individual, thirty-seven years of age, in whom marked subjective noises, attacks of dizziness, and headache suddenly appeared, which were later followed by disturbances of hearing. At the autopsy he found: Thickening of the periosteum of the vestibule, the foot of the stapes raised and immovable, the connective tissue between the membranous and bony labyrinth infiltrated with small cells and hyperplastic, Corti's organ and semicircular canals infiltrated with cells, and the acoustic nerve normal. Moos and Steinbrügge (*Z. f. O.*, vol. xiv.) found in a deaf individual who had tertiary syphilis, enlargement of the osseous spaces in the temporal bone and in the labyrinthine capsule, which were infiltrated with small cells, extravasations of blood between the fibres of the acoustic nerve and in the cochlea, and degeneration of the ganglionic layer in Rosenthal's canal, as has already been shown by the author. Downie (*Z. f. O.*, vol. xxx.) observed a boy with hereditary syphilis who became deaf with symptoms of pain and buzzing in the ear, and who died shortly after with symptoms of bulbar paralysis. The middle ear was normal, the stapes had undergone bony ankylosis, and the internal auditory canal was greatly constricted; the vestibule and semicircular canals were filled with newly-formed bony tissue, and the cochlea was narrowed by thickening of the modiolus and lamina spiralis. Manasse (*Vers. deutscher. Naturf. u. Aerzte*, 1899) found in a syphilitic patient who presented the picture of deafness of a nervous nature small, multiple, round-cell infiltration in the course of the acoustic nerve, and at its place of entrance into the cochlea, which he considered as a specific infiltration; in a second case (*Zeitschr. für Ohrenheilk.*, vol. xxxix.), he found new formation of connective tissue in the scala tympani and vestibuli, as well as in the perilymphatic spaces of the vestibular apparatus of both labyrinths. Furthermore, there was an abundant infiltrate, which partly resembled lymphomatous tissue, in both acoustic nerves.

The author observed a man, fifty years old, who had been deaf ten years in consequence of a syphilitic infection, and who died of phthisis. The histological examination showed that the ganglion spirale had undergone the greatest change. In this canal there were partly small, round, granular cells without a distinct nucleus, and partly oval, angular bodies, in only a few of which the nucleus could be recognized (atrophy and destruction of the ganglionic cells in the spiral ganglion). On the spiral membrane, in the vestibule, and in the semicircular canals, no changes were visible. Moos and Steinbrügge found atrophy and degeneration of the ganglionic cells in Rosenthal's canal, and in addition atrophy of the acoustic fibres lying between the layers of the lamina spiralis ossea, especially in the region of the first turn of the cochlea.

The syphilitic diseases of the auditory nerve are usually associated with affections of the labyrinth, yet they may appear alone, and then become evident as a neuritis, or, in other words, a perineuritis gummosa, less often, however, as a basilar gummatous meningitis (Rosenstein, *Arch. f. Ohrenheilk.*, vol. lxv.); there is seldom a pressure atrophy of the acoustic nerve, owing to a periostitic deposit on the inner table of the internal auditory canal (Zeissl, *Konstitutionelle Syphilis*, Erlangen, 1864).

The changes in the bloodvessels in syphilis, as described by Heubner, have

been seen in only one case recorded by Baratoux and Kirchner. They found a typical syphilitic endarteritis in the bloodvessels of the mucous membrane of the tympanic cavity, periosteal lenticular accumulations of bone on the promontory, and the formation of cavities in the wall of the labyrinth (identical with the conditions found in otosclerosis, as described by the author). No anatomical changes have yet been observed in the nuclei of the auditory nerves.

Symptoms.—Syphilis of the labyrinth (cochlitis, Roosa) usually appears suddenly with subjective noises, dizziness, disturbances of equilibrium, and marked deafness. The impairment in hearing is less often of a progressive character in this affection than in otosclerosis. The subjective noises, which are generally very intense, continue uninterruptedly even after deafness has become complete, while the dizziness and disturbances of co-ordination may disappear within a few months. Roosa has observed diplacusis in syphilitic affections of the labyrinth, while Moos and Steinbrügge (*C. f. O.*, vol. xiv.) have noticed sensations of pain in the ear, which could be traced to a periosteal growth in the labyrinth.

Bárány (*Jahrb. f. Psychiatrie*, 1907) observed in a syphilitic person with normal hearing that there was a nystagmus towards the healthy side, and that the vestibular apparatus did not respond to caloric irritation, or when the body was rotated on its long axis. He attributed these symptoms to an isolated luetic affection of the vestibular apparatus.

The objective examination shows either a normal condition of the membrane, or changes which have been brought about by an existing or by an exhausted middle-ear affection. In two instances the author found peculiar, sharply-defined, white patches on the membrana tympani. The Eustachian tube is permeable, swollen—if there be a co-existent naso-pharyngeal affection and middle-ear catarrh—constricted, or, in syphilitic ozæna, occluded by crusts. The author has repeatedly found the lymph-glands in the region of the mastoid process intensely swollen.*

The disturbances of hearing are marked in the majority of cases. The affection is seldom unilateral; when it is bilateral, the one ear is generally more affected than the other. The hearing distance for the watch and acoumeter is greatly reduced even in mild cases; in severe cases it is *nil*. Inflations of air have a very slight influence upon the hearing distance. The perception for the watch and acoumeter through the cranial bones is entirely lost. In unilateral affections the tone of the tuning-fork is always lateralized towards the normal or better-hearing ear, while in bilateral total deafness the perception for the tone of the tuning-fork is entirely wanting. In cases in which the disturbance of hearing is of a high degree, Rinne's test is generally

* Cp. St. J. Roosa, *Z. f. O.*, vol. ix., p. 303; same author, *Syphilis of the Cochlea* (*Medical Record*, vol. xlvii.).

positive; in total deafness it sometimes seems negative, as the patients mistake the sensation of vibration for the sensation of sound. In the majority of cases high tones are not as well perceived as low ones.

Course and Terminations.—The course of syphilis of the labyrinth is characterized by the rapid development of disturbances of hearing. The author has seen cases in which the deafness was almost complete on the third day. It is more often noticed, however, that the hardness of hearing develops gradually, and that it remains stationary for some time, until, after weeks or months, a sudden change for the worse takes place. Decided variations in the hearing distance are rarely met with. The author has found that even slight concussions of the head are sufficient to bring about a marked change for the worse. Where an improvement or recovery is obtained, it is found that this rarely takes place suddenly, but gradually. As the improvement progresses, the perception through the cranial bones also returns.

Diagnosis.—The diagnosis of syphilis of the labyrinth may be made with certainty if symptoms of secondary syphilis are found in other parts of the body, as on the skin and mucous membranes, or in the eye; if there is a history of a former general syphilitic infection; and if the disturbances of hearing develop rapidly with the symptoms previously mentioned. The suspicion of syphilis of the labyrinth is aroused if we find, especially in a young person, a rapid increase in the deafness with absence of the objective symptoms of a middle-ear affection. In those cases in which there is a present or past syphilis and the middle ear becomes affected, it may be concluded with great probability that there is a co-existing syphilitic affection of the labyrinth, from the rapid manner in which the disturbance of hearing develops, and from the absence of perception, or from a greatly shortened perception for the tone of the tuning-fork through the bones of the head. The diagnosis is more difficult if disturbances of hearing develop gradually, and not until some years after the general syphilis has run its course. This is explained by the fact that in such cases the development of an otosclerosis, independent of a past syphilis, cannot be excluded. As children give contradictory answers while testing their hearing, thereby rendering such tests of little value, a more positive diagnosis can be made only from the objective symptoms. In all cases of sudden deafness in which the tuning-fork tests show a labyrinthine lesion—that is, a nerve deafness—and in which there may or may not be a history of a previous syphilitic infection, a Wassermann test must be taken. When positive, it allows us to assure that the aural lesion is of a luetic nature, and should be followed up by a vigorous antisyphilitic treatment.

Those forms of severe hardness of hearing or total deafness

which usually develop in both ears during childhood must be regarded as syphilitic affections of the labyrinth of a hereditary character. Such cases were formerly supposed to be due to scrofula. According to Hutchinson and Jackson, the ears are affected in 10 per cent. of all children who have hereditary syphilis, and according to Hermet and Baratoux, in óne-third of all cases. The last-named author found in new-born children with congenital syphilis a purulent inflammation of the middle ear, thickening of the membrana tympani, adhesion of the same to the promontory, hyperæmia, hæmorrhages and accumulations of pus in the labyrinth, and destruction of the organ of Corti. The anatomical changes which take place in the later stage are not known. The hereditary form of syphilis of the labyrinth is often associated with adhesive processes of the middle ear, and with marked opacity of the cornea arising from chronic interstitial keratitis, the syphilitic nature of which has been frequently demonstrated. According to Hutchinson,* the disease is also characterized by the simultaneous characteristic changes in the teeth (Hutchinson's Triad). Hereditary syphilis of the labyrinth is more often met with in females than in males. According to Hinton, disturbances in hearing often arise only at the time of puberty (syphilis hereditaria tarda).

Prognosis.—The prognosis of syphilis of the labyrinth is unfavourable; generally, however, the outlook is more favourable in the recent than in the old forms. The degree of disturbance of hearing does not always allow us to give a prognosis as to the ultimate outcome, as at times recovery may ensue in spite of the fact that the patient is totally deaf, while at other times the milder forms remain incurable, notwithstanding an energetic antisyphilitic treatment, and may even become worse in the course of time. Circumstances which render the prognosis unfavourable are: Advanced age, anæmia, marasmus, a severe, incurable, general syphilis, simultaneous adhesive processes in the middle ear, and strictures of the Eustachian tube. The hereditary forms associated with opacity of the cornea, as mentioned above, are also incurable. The author's experience has shown that the improvement in hearing may again disappear entirely, and that when this is the case the hearing is lost for ever. Since the introduction of salvarsan, the prognosis of acquired syphilis of the labyrinth is more favourable, as the hearing is regained in the majority of cases after an energetic antisyphilitic treatment. Even in cases in which the hearing becomes worse, or is completely lost, after the injection of salvarsan one can still give a favourable prognosis, because the hearing generally

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* *Arch. of Surgery*, 1897; Kreuzer, *Zur Hutchinson'schen Trias* (Diss. Inaugur., München, 1897); Schwabach, *Ueber ererbte syphilit. Ohrleiden.* (*Deutsch. med. Wochenschr.*, 1883); Hennebert et Brockaert, *Syphilis de l'oreille* (*Bullet. de la société Belge d'otolog.*, etc., 1897).

returns or becomes normal again after another course of treatment with this drug.

Treatment.—The treatment of syphilis of the labyrinth is the same as that of the general infection. When the diagnosis of syphilis has been confirmed by the result of the Wassermann test, we must begin treatment with the intravenous injections of salvarsan. This sometimes causes a marked diminution or even a complete loss of the hearing, which, however, is regained, in the majority of cases, after one or more injections of salvarsan. This disturbance in the hearing is supposed to be due to a neuritis of the auditory nerve which is brought about by the awakening or stimulation of the spirochætæ, which lie dormant in the internal auditory canal. When the salvarsan is given again the spirochætæ are destroyed, the inflammatory condition of the nerve gradually subsides, and the hearing returns to its former state. In addition to the salvarsan treatment, one should also resort to the use of mercury and the iodides. The mercury may be given hypodermically or in the form of inunctions. The concentrated solutions of sodium or potassium iodide may be given in increasing doses, beginning with 10 to 100 minims three times a day. The author has obtained favourable results in recent forms of labyrinthine syphilis by the subcutaneous injections of a 2 per cent. solution of the muriate of pilocarpin in increasing doses from 4 to 10 minims every second or third day.

In addition to the general treatment, injections of a potassuim iodide solution through the catheter into the tympanic cavity, and inunctions of an iodoform, iodol, iothion, or mercurial ointment behind the ear may be used. If the disease has not caused too many destructive changes in the labyrinth and in the nerve-endings in the cochlea, the hearing will shortly return to its former stage by this method of treatment. In a number of cases, however, the lost function remains in spite of the most energetic antisyphilitic treatment.

Up to the present time we possess only a few observations as to the changes in the labyrinth in rickets. Moos and Steinbrügge (*Zeit. f. Ohrenheilk.*, vol. xi.) found at the necropsy of a dumb idiot who had been deaf from the time of his birth, and who had general hyperostosis of the cranium, the following changes, which, according to the view of Virchow, were of a rachitic nature: Hyperostoses on the inner tympanic wall, great contraction of the internal auditory canal, ossification of the ligamentum annulare, and a mass of tissue consisting of cartilage cells and fibrous plugs, with a small calcareous deposit in the capsule of the right cochlea near the recessus hemisphæricus. At the same time, the congenital anomaly of an incomplete ossification of the Fallopian canal was found on both sides. In the left ear the foot-plate of the stapes was wanting, and was replaced by a bony mass which extended into the osseous substance of the labyrinthine capsule. In the right ear, instead of the crura of the stapes, slipper-shaped bands were seen, which were ossified only at their external periphery, and between which a connective and adipose tissue rich in cells was deposited.

In Professor Wagner v. Jauregg's* exhaustive and instructive work on cretinism, reference is also made to the disturbances of hearing arising in endemic and sporadic cretinism. Wagner expresses the opinion that all true symptoms of cretinism (imbecility, disturbances in development, speech and hearing) may be explained by some disorder—that is, lack of function of the thyroid gland, with its subsequent infantile myxœdema. Wagner also informs us that disturbances of hearing often occur in the myxœdema of adults. He supports his statement by the report of the Myxœdema Committee of the London Clinical Society, which found among 109 adults affected with myxœdema a disturbance of hearing in half of the cases. Its connection with myxœdema was proved by the fact that the deafness, and the other symptoms of myxœdema, were cured by the thyroid treatment.

According to the investigations carried out by Alexander in cretins at Wagner's clinic, a large percentage of cretins are hard of hearing. In addition to acute and chronic middle-ear catarrhs owing to an enlargement of the pharyngeal tissue, affections of the sound-perceiving apparatus were also found. In the organs of hearing of four cretins, to which must also be added a deaf-mute, Alexander found the following changes: Atrophy of Corti's organ, pathological bony areas in the capsule of the cochlea, changes in the tractus spiralis foraminulentus, analogous to those found by the author in otosclerosis, and finally, in three cases, the fatty tissue in the niche of the round window first described by the author in chronic middle-ear inflammations and in deaf-mutism.

According to Habermann (*Deutsch. Otologentag*, 1904) the disturbances in hearing in cretinism are due to a faulty development of the organ of Corti, or to changes in the brain.

Bloch (Freiburg) (*Deutsch. Otologentag*, 1904) is inclined to believe that there is a (cretinistic) hardness of hearing owing to a faulty development of the thyroid gland, which is brought about by a sort of toxic neuritis, and which attacks the auditory nerve, just as the other cranial and spinal nerves. Siebenmann (*Archiv f. Ohrenheilk.*, vol. lxx.) found no changes in the labyrinth in a case of total aplasia of the thyroid gland; still, this one single case, in which the hearing was not examined during the life of the patient, does not disprove the clinical observations of Bloch.

VII. Diseases of the Acoustic Nerve.

Anatomical Changes in the Acoustic Nerve.

Hyperæmia of the neurilemma of the auditory nerve is often found in conjunction with congestion of the meninges, particularly in meningitis, encephalitis, in aneurism of the basilar artery, and especially in stasis of the vessels of the brain.

Ecchymoses in the root of the nerve have been observed in association with fractures of the petrous bone, in scurvy, in fatty degeneration of Corti's organ, in leukæmia, in degenerative atrophy of the auditory nerve, and in syphilis of the ear.

Purulent inflammation and infiltration of the acoustic nerve have been seen in purulent basilar meningitis, in epidemic cerebro-spinal meningitis, in diphtheria, in suppuration spreading from caries and necrosis of the petrous bone (see p. 556), and after fracture of this bone. Sclerosis of the ramus cochlearis as a result of an exhausted neuritis is reported by Siebenmann (*Zeitsch. f. Ohrenheilk.*, vol. xliii.) in a woman, fifty-one years of age, who had been deaf twenty years. A marked sclerosis of the auditory nerve, with the deposit of a great number of hyaline globules, was found by Brühl (*Zeitsch. f. Ohrenheilk.*, vol. l.) in a case of otosclerosis.

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* *Ueber endemischen und sporadischen Cretinismus und dessen Behandlung* (*Wiener klin. Wochenschr.*, 1900, No. 19).

Hypertrophy of the root of the auditory nerve, brought about by infiltration and growth of its neurilemma, is of rare occurrence. The author found it in cases of extensive caries of the petrous bone in association with nodular thickenings of the facial nerve.

Rheumatic paralysis must be added to the affections of the acoustic nerve, which, if judged from its clinical cause, is most likely brought about by a neuritis. The observations in reference to this affection are few and rather unreliable. Hammerschlag (*Archiv f. Ohrenheilk.*, vol. vii.) called attention to this rare affection.

In making a diagnosis we must chiefly consider the etiological factors—that is, the primary cause of the rheumatism, the course, and the complication with rheumatic paralyses of other cranial nerves, and with rheumatic affections of other parts of the body. The auditory nerve apparatus may become affected alone, as is shown by a case reported by Bing (*Wiener med. Wochenschrift*, 1880), or in conjunction with the facial nerve. Rheumatic paralysis of the acoustic nerve is less often associated with a paresis or with an anæsthesia of the parts of the skin and mucous membrane supplied by the trigeminus, or with herpes zoster.*

The symptoms of rheumatic paralysis of the auditory nerve vary according to whether the cochlear portion of the nerve is affected alone, or whether the vestibular portion is also involved in the process. In the latter case we notice severe dizziness, the inability to walk straight or to stand with closed eyes, and at times a complete incapacity to rise in bed, which is associated with nausea and vomiting. That the cochlear portion is involved is apparent by a disturbance of hearing of a varying degree, and by the results of the tuning-fork tests, which are characteristic of a primary, uncomplicated affection of the labyrinth (*vide* p. 152). The course of this disease is such that the vestibular symptoms disappear first, while the disturbance of hearing returns to its normal condition only at a later stage. In a number of cases, a permanent disturbance of hearing remains. The pathology of this form of disease is yet unknown; Hammerschlag believes that it is analogous with a similar affection of the facial nerve, and that it may possibly be due to a neuritis of the terminal filaments of the acoustic nerve in the labyrinth. The treatment consists in the application of the galvanic current over the mastoid regions, whereupon it is noticed that there is generally an increased irritability of the acoustic nerve. In addition to the

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* Cp. the observation of the combination of herpes zoster with facial paralysis as first observed by the author on p. 217. (D. Kaufmann, *Zeitsch. f. Ohrenheilk.*, 1897; Hammerschlag, *Archiv für Ohrenheilk.*, vol. xlv.; Körner, *Münch. med. Wochenschr.* 1904; Sarai, *Zeitsch. f. Ohrenheilk.*, 1904; Lannois, Congrès de Bordeaux, 1904; Gradenigo, *Ann. d. mal. d. l'orielle*, 1908, v. Frankl-Hoehwart, *loc. cit.*)

use of the galvanic applications, one should prescribe the usual anti-rheumatic treatment. In the majority of cases a return to the normal usually ensues within a short time, even when no treatment has been given, so that, as a rule, the prognosis is favourable.

In a case of Bing, a woman forty-seven years of age was exposed to a draught; this was followed by complete deafness, accompanied by subjective sensations of sound in the right ear, and by a marked impairment in hearing, with a normal condition of the membrana tympani in the left ear. In performing Weber's test the tone of the tuning-fork was perceived only in the left ear, and inflations of air remained without any effect upon the hearing distance. Recovery took place in eight days from the internal administration of potassium iodide and the application of vesicants to the mastoid process. In a man, sixty-one years of age, who had suffered from articular and muscular rheumatism, marked tinnitus and a high degree of deafness suddenly appeared in the right ear without any attacks of dizziness. An examination made after the disturbance of hearing had lasted four weeks revealed nothing wrong in the membrana tympani or the Eustachian tube, a greatly diminished acuteness of perception for the acoumeter and for speech, a reduced perception for the acoumeter through the cranial bones, a loss of perception for the tone of the tuning-fork in the affected ear through the bones of the head, and a positive Rinne.

Moos reported the case (*A. f. A. u. O.*, vol. i.) of a girl, nineteen years of age, who was taken ill with articular rheumatism, which ran its course with severe nervous and cerebral symptoms. In the seventh week of the affection there was a hyperæsthesia of the ear, which was soon followed by total deafness, and tormenting subjective noises, which soon disappeared without an improvement in the hearing. Examination with the speculum did not reveal anything abnormal. By applying the galvanic current the hearing gradually returned to its normal state.

Haug and Morpurgo report similar cases. Combinations of rheumatic affections of the auditory nerve with facial paralysis have been described by Rosenbach (*Centralbl. f. Nervenheilk.*, 1887) and v. Frankl-Hochwart (*Der Menière'sche Symptomencomplex*, Wien, 1897).

According to Ogston, the paroxysms of deafness and subjective sensations of sound which arise during the course of gout and chronic rheumatism may be compared to the attacks of glaucoma met with in arthritic patients.

The disturbances of hearing, which are usually unilateral, and which are not infrequently observed during influenza (p. 455), may also be considered as a neuritis of the acoustic nerve. In these cases the objective examination of the external and middle ear shows nothing abnormal, but the tuning-fork tests (lateralization from the vertex towards the normal ear, positive Rinne, lost or shortened perception through the cranial bones, perception for the deep tones through air conduction) demonstrate a paralysis of the sound-perceiving apparatus. The occurrence of this form of acoustic paralysis is confirmed by Gradenigo, Barnick (*A. f. O.*, vol. xxviii.), and Lannois (*Rev. hebd. de Larnygol.*, etc., 1890). Complete recovery seldom took place in the cases observed by the author.

A case of isolated rheumatic affection of the vestibular nerve has been reported by Ruttin (*Sitzung d. öst. otol. Ges.*, January, 1908). There was a marked spontaneous nystagmus towards the healthy side; the caloric reaction (Bárány) was absent. Recovery took place at the end of three weeks. The hearing was not impaired during the entire course of the disease.

Clinical observations and anatomical investigations of neuritic affections of the auditory nerve have been published by Sporleder, Wittmaack, Manasse, Brühl, Frankl-Hochwart, and others. The

various infectious diseases which are regarded as the etiological factors in producing a neuritis of the acoustic nerve are: Tuberculosis, typhoid fever, scarlet fever. syphilis, rheumatism, and influenza. The hardness of hearing or deafness which arises after the use of quinine and salicylic acid, and is associated with subjective noises, is due to a toxic neuritis of the acoustic nerve in which its ganglion cells are mainly involved.

Wittmaack (*Zeitschr. f. Ohrenheilk.*, vol. liii.) reported two cases of acute isolated neuritis of the cochlear nerve in scarlet fever. Sporleder (*Sitzungsber. d. deutsch. otol. Gesellsch.*, 1900) reports the case of a woman who had become deaf after an attack of typhoid fever, and in whom the auditory nerve had undergone connective-tissue degeneration as a result of a neuritis. Neuritis leads, in many cases, to a secondary degeneration and atrophy of the nerve elements. A primary atrophy of the auditory nerve can develop without a previous inflammation. It also develops as the result of a contraction of the basilar and internal auditory artery and in aneurisms of the former bloodvessel; it is also seen as the result of an apoplectic and encephalitic process in the floor of the fourth ventricle and in the region of the nucleus and roots of the acoustic nerve, and in hydrocephalus and in otosclerosis.

Sporleder (*loc. cit.*) found degeneration of the auditory nerve, with marked atrophy of the cochlear nerve, in severe cases of marasmus, while Brühl observed a parenchymatous degeneration of the acoustic nerve in old persons. Manasse (*Verh. deutsch. Naturf. u. Arzte*, 1899) saw in a phthisical patient who became gradually deaf, and in whom the labyrinth was normal, a degeneration of the acoustic root, which was visible as a disseminated patch consisting of fine fibrous masses. Meyer of Gottesberge (*Monat. f. Ohrenheilk.*, 1903) saw a case of neuritis of the acoustic nerve, which began with symptoms of a polyneuritis, and which was associated with a simultaneous neuritis of the trigeminus, occipital, median, ulnar, and peroneal nerves.'

Atrophy of the root of the auditory nerve has also been shown to be due to peripheral changes in its terminal filaments in the labyrinth. O. Weber (*Pitha u. Billroth*, i.) found fatty degeneration of the roots and nucleus of the acoustic nerve after destruction of the labyrinth. Secondary changes in the nerve are also met with in purulent inflammations of the labyrinth (see p. 556), and in those cases in which a caseous exudate is deposited in the labyrinthine cavity. In a case of typical otosclerosis examined by the author, in which the *post-mortem* examination revealed ankylosis of the stapes and partial ossification of the cochlea, the fibres of the acoustic nerve were atrophied to a marked degree. In a case reported by Schwartze, in which the stapes was ankylosed in both ears, the auditory nerve was atrophied only on one side. Panse described a parenchymatous neuritis, with secondary degeneration of the spiral ganglion and organ of Corti, and slight changes in the papilla basilaris in the upper turn of the cochlea.

The question whether deafness of long standing may lead to atrophy of the auditory nerve from inactivity cannot be positively determined, as it not infre-

quently happens that the roots of the auditory nerve are not only found unchanged in ankylosis of the stapes which has existed for some time, but also in congenital deaf-mutism. In those cases in which there are changes, it is questionable whether the atrophy is due to an inactivity or to a neuritic affection of the auditory nerve.

Secondary atrophy in the terminal filaments of the auditory nerve in the cochlea and in the spiral ganglion seems, according to the author's experience, to occur frequently. We must mention here Moos and Steinbrügge's carefully observed case in which the nerve was found atrophied in the first turn of the cochlea, and the movements of the stapes in the oval window limited. In this case the perception for high tones was diminished to a marked degree.

The same applies to the atrophy of the large ganglionic layer in the canalis ganglionaris (Rosenthal's canal), which establishes a communication between the nerve-bundles entering the cochlea and those in the lamina spiralis (p. 80). The following case is of interest:
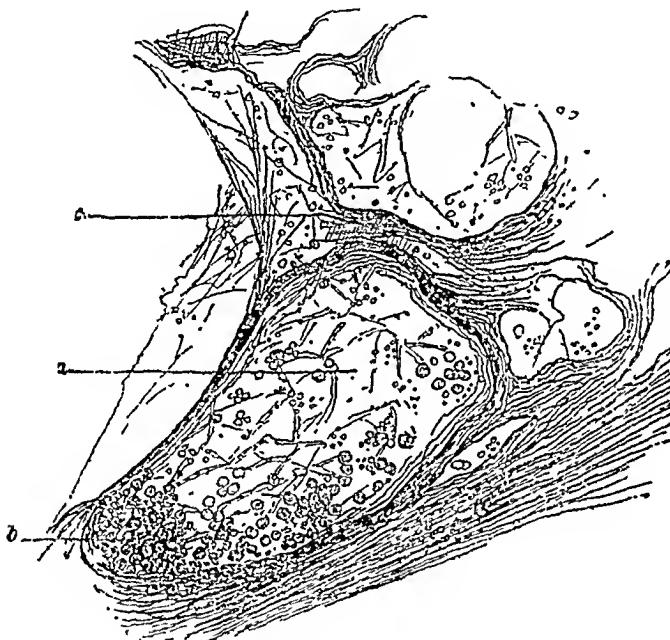
FIG. 288.

The patient was a boy nine years of age, who became totally deaf in his fourth year during an acute illness which lasted eight days, and which was accompanied by unconsciousness; death resulted from an acute encephalitis. The autopsy showed: right middle ear, normal; left, an extensive destruction of membrana tympani as the result of a middle-ear suppuration which had run its course. In microscopic sections one could see in the first turn of the cochlea, at the place of transition from the first to the second turn, and in Rosenthal's canal (Fig. 288, *a*), a small number of round and angular bodies (*b*), which upon minute examination proved to be the remains (nuclei) of the ganglionic layer, the cells of which had disappeared to a greater part, while a small portion remained as shrivelled, granular bodies. The cavity of Rosenthal's canal was filled with a delicate network, in which only a few nerve elements were visible. The nerve bundle (*c*) entering the lamina spiralis ossea from Rosenthal's canal had disappeared entirely, and the place where Corti's cells were situated was marked by a layer of epithelium which was somewhat raised. The striæ acusticæ were imperfectly developed, but no anomalies were found in sections of the acoustic nuclei and roots

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Habermann saw atrophy of the auditory nerve-endings in the canalis ganglionaris and in the lamina spiralis, and degeneration of Corti's organ in the uppermost turn of the cochlea, in consequence of a depression of the skull acquired eight years before death. Bezold and Scheibe (*Z. f. O.*, vol. xxii.) observed marked degeneration of the nerve-fibres and of the ganglionic cells in a man sixty-one years of age, who had been very deaf, and whose loss of hearing progressively increased.

We will mention here briefly the most recent findings as to progressive nervous deafness. Several years ago the author* called attention to a nerve deafness which runs its course without symptoms, and which appears in young and old individuals. This form of deafness is characterized through its progressive course, and through its lack of labyrinthine and cochlear symptoms of irritation. From the results of the functional examinations, which are indicative of a labyrinthine deafness, the author expressed the opinion that there must be in these cases, a primary atrophy of the auditory nerve.

The first thorough anatomical examination of labyrinthine progressive deafness was made by Alexander (*Archiv f. Ohrenheilk.*, vol. lvi.), who found atrophy of the cochlear nerves and of Corti's organ. We are indebted to Manasse (*Deutsch. Otologentag*, 1905, and *Monograph*. Wiesbaden, 1906) for a complete compilation of this form of disease, and for his thorough description of this affection, based on a large clinical and anatomical material. According to his investigations, chronic, progressive labyrinthine deafness seems to be of frequent occurrence. He found that the anatomical causes of this affection were: atrophy (that is, degeneration) of the nerve elements, and new formation of connective tissue in the ductus cochlearis, in the spiral ganglion, in the delicate branches of the auditory nerve in the cochlea, and in the root of the nerve itself. The affection begins in the auditory nerve-root, from which it extends towards the periphery to the organ of Corti (*Atrophy of the Sense Cells*, Alexander). Contrary to Manasse, Wittmaack found that the affection was confined only to the root of the cochlear nerve, while the cochlea itself was not involved in the process.

The cases seem to be of less frequent occurrence in which the changes take their origin from the ductus cochlearis, or remain confined to it entirely. A case of this nature was reported by Alexander (*Archiv f. Ohrenheilk.*, 1907). The terminal filaments of the nerve in the saccule and utricle and in the semicircular canals, in addition to the small nerve-branches, may remain unaltered. In the minority of cases they also undergo a degenerative atrophy, which is associated with a complete destruction of the labyrinthine epithelium and with a marked atrophy of the nerve-roots.

Manasse observed that chronic progressive labyrinthine deafness occurred mostly in old individuals of the male sex, and generally on both sides. He thinks it is due to arterio-sclerosis, tuberculosis, syphilis, chronic nephritis, and also to middle-ear inflammations. Seligmann (*Monat. f. Ohrenheilk.*, vol. lx.) thinks progressive nerve deafness is due to an exhaustion of the general nervous system. Manasse, as well as the author, calls attention to the typical symptoms of the labyrinthine deafness with the absence of disturbances of equilibrium.

The prognosis of this affection is unfavourable. It develops now and then to a certain degree of deafness, where it remains stationary, but leads, however, in many other cases to complete loss of hearing.

Colloid degeneration of the auditory nerve was found by Moos at the autopsy of an insane individual, who had total deafness on the right side, marked impairment of hearing on the left, hallucinations of sound, and, in addition, a simultaneous ankylosis of the ossicles, and bony closure of the round window. The occurrence of amyloid bodies in the auditory nerve are significant of a degenerative process only when these bodies are present in

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* *Text-Book of Diseases of the Ear*, fourth edition, 1901, p. 784, English edition.

very large masses, as they are also found in the nerve in varying quantities under normal conditions.

In the course of the cochlear nerve, at a short distance from the medulla oblongata, and often in the internal auditory canal, there is found a gliomatous septum which is either in the form of a cupola or very jagged, and which separates the peripheral from the central part of the auditory nerve (Hulles). Obersteiner and Alexander (*Zeitsch. f. Ohrenheilk.*, vol. lv.) have shown that corpora amylacea (the origin of which has recently been demonstrated by Redlich and Obersteiner to spring from the nerve tissue) are present in this septum, which increase in the course of years, just as in all gliomatous structures —a condition which is not to be regarded as an artificial or a pathological process.

Böttcher (*Virch. Arch.*, vol. xvii.) has repeatedly noticed in middle-aged persons calcareous deposits in the periosteum of the internal auditory canal and in the neurilemma of the auditory nerve. Moos believes that the disturbances of hearing, subjective noises, and contractions of the muscles of the face observed in one of his cases (*A. f. A. u. O.*, vol. iii.) during the life of the individual, could be attributed to deposits of phosphate of lime in the auditory nerve.

New Growths in the Internal Ear.

Primary new growths in the internal ear are much less often met with than the secondary neoplasms, which extend from the middle ear or cranial cavity into the labyrinth and involve the auditory nerve.

Little is known of primary new growths of the labyrinth, as the few *post-mortem* findings reported in literature are so deficient and of so little scientific value that the author can merely refer to them.

We do possess, however, positive data in reference to primary new growths occurring in the root of the auditory nerve itself, such as the sarcoma and the so-called acoustic neuroma. The former has been repeatedly seen by Förster (*Wurzb. med. Z.*, iii.), and in one case by Voltolini (*Virch. Arch.*, xxii.). According to Sternberg (*Zeitsch. f. Heilk.*, 1900), acoustic tumours are mixed growths of a gliomatous character. They arise from the acoustic nerve itself, but are sometimes entirely independent of it. Not infrequently one finds multiple growths in addition to a general neuro-fibromatosis. In reference to their symptoms, which do not differ from those of other tumours of the posterior cranial fossa, the reader is referred to the chapter on ' Cerebral Disturbances of Hearing.

In the great majority of cases new growths of the internal ear, which extend to the labyrinth or to the root of the auditory nerve from the middle ear or cranial cavity, must be regarded as secondary neoplasms.

The epitheliomata and the malignant round-celled sarcomata are those new growths of the external and middle ear which also involve the petrous bone and the labyrinth. In a patient forty-seven years of age, observed by the author, an ulcerating epithelioma, which presented the symptoms of a chronic middle-ear suppuration with the formation of polypi, developed on the mastoid process, and extended to the petrous portion of the temporal bone and cranial cavity. Death resulted from an erysipelas of the face and head.

The microscopic examination of the labyrinth showed the following (Fig. 289):

At the promontory wall corresponding to the apex of the cochlea there was a perforation, through which the neoplasm forced its way into the interior of the cochlea. The lamina spiralis in the second and third turns of the cochlea was perforated here and there, and the scala tympani and vestibuli were partly filled with masses of cancer cells, which were distributed in groups (*b*).

The condition in the first turn of the cochlea was of special interest: the lamina spiralis was intact; in the scala vestibuli a group of cancer cells was found on the external wall of the ductus cochlearis, which extended along the basilar membrane to the organ of Corti (*c, c′*). In the scala tympani of

the one side there was visible on section, a lobulated, cancerous tubercle (*d*) on the external and inferior walls of the cochlea, which almost filled two-thirds of the scala tympani (*e*). A connective-tissue band extended directly across the latter, and joined the connective-tissue lining membrane which had been detached from the inner wall of the cochlea. In some of the sections it
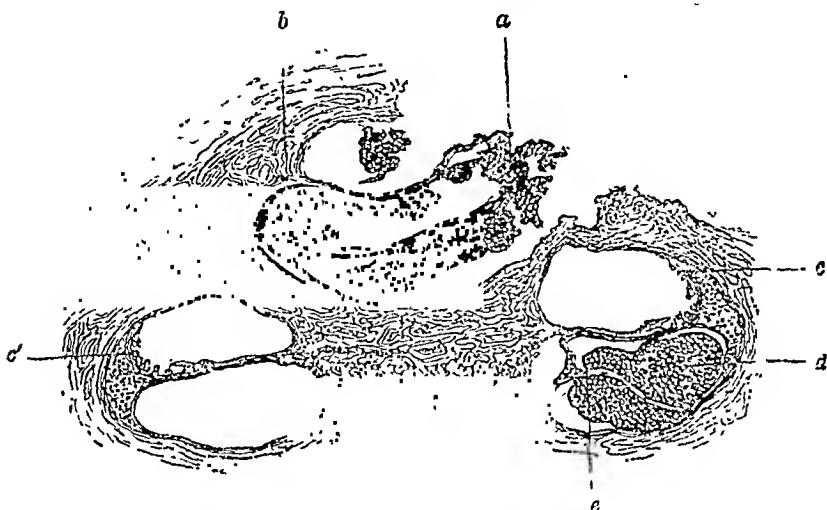
Fig. 289.

could be seen that the cancerous mass had penetrated into the internal auditory canal, and that it also involved the root of the nerve.

Cavernous angioma of the petrous bone, which was first observed by the author, is one of the rarest forms of new growths of the internal ear.

A case of this nature is that of a girl, twelve years of age, who suffered for a year and a half from a right-sided otorrhœa and occasional hæmorrhages from the ear.

Fig. 290.

For several months there was a right-sided facial paralysis. *Status præsens :* A bluish-red polypoid growth which reached to the middle of the external auditory canal, and which bled profusely on the slightest touch; roughness of the bone on the posterior wall of the meatus; marked deafness, and an increased perception for the tones of the tuning-fork through the cranial bones

on the affected side. During the time of observation there were severe hæmorrhages and a rapid regeneration of the growth.

Dyspnœa and cyanosis suddenly set in, and death followed with symptoms of asphyxia.

Post-mortem Examination.—The middle of the posterior osseous wall of the auditory meatus was perforated by two irregular openings half the size of a lentil, which led into the cavity of the mastoid process; through the one perforation a tumour the size of a pea, and through the other, a smaller one of a bluish-red colour with a smooth surface, grew into the meatus. At the posterior part of the membrana tympani an oval perforation was found, through which several ragged growths had forced their way.

An irregular, nodular, ovoid tumour about the size of an orange was also discovered at the base of the skull, which occupied the entire right petrous portion of the temporal bone, and which extended forwards into the right middle, and backwards into the posterior, cranial fossa.

The entrance into the internal auditory meatus was greatly contracted. The acoustic and facial nerves were thin, and of a light gray colour. In a section through the petrous bone (Fig. 290), the bone was found to be traversed by numerous small and large cavities (*c*), from the walls of which round and irregular exerescences grew into their lumens; from the upper part of the petrous bone (*b*) a radiating osseous framework (*a*) arose, which was composed of strong osseous lamellæ, and to the upper edge of which a large cavernous framework was attached (*d*), which contained a sanguineous fluid and coagula. The microscopic examination of the polypus, which had been removed from the external meatus, showed that it was a cavernous angioma with branching ridges of bone, and that it was in communication with the new growth in the petrous bone. The tumour probably had its origin in the lateral sinus, which communicated with the cavities of the cavernous angioma. The inferior parts of the right temporal and occipital lobes were deeply depressed, corresponding to the size of the growth; the cerebellum and medulla oblongata were laterally compressed, and pushed to a marked degree towards the left side.

Neuroses of the Acoustic Nerve Apparatus.

The affections of the acoustic nerve, which are associated with a diminution or loss of the hearing function, are produced, as already mentioned, by anatomical changes in the labyrinth, in the root of the nerve, and in its central course. There is no doubt, however, according to clinical observations, that functional paralyses of the acoustic nerve do occur which are not caused by any demonstrable anatomical change.

I. Hyperæsthesia.

Under this heading the following must be classed:

1. Hyperacuteness of Hearing (Oxyecoia).—This is characterized by an occasional striking increase in the acuteness of hearing, which may be either for every kind of tone and noise, or only for certain sounds. During such phases, which generally last from one to two hours, the individual is able to hear speech or music at a greater distance than usual or from distant rooms (as, for instance, the neighbouring apartment), while those persons whose hearing is normal may only perceive the sounds indistinctly.

Hyperacuteness of hearing is of very rare occurrence, and very little trustworthy information regarding this form of neurosis can be found among the works of older authors. According to the author's observations, it generally affects nervous, hysterical and neurasthenic persons whose hearing is otherwise normal. The most frequent etiological factors are: mental excitement, and slight congestion of the head following the use of alcoholic beverages or nicotine poisoning. The author has repeatedly observed a temporary acuteness in the hearing after the cessation of a mild catarrh of the tube and tympanic cavity, and after the removal of a plug of cerumen. There is almost invariably a co-existing sensitiveness to noises. Sometimes oxyecoia appears as the forerunner of meningitis, encephalitis, or an intracranial affection of the acoustic nerve. Urbantschitsch observed it in the beginning of febrile diseases, with marked affections of the mind, and after chloroform anæsthesia; Charcot states that he noticed it during hypnotism.

II. Paracusis.—The qualitative change in the perception of hearing (false hearing), which most frequently becomes apparent by a false interpretation of pitch, must not always be considered a symptom of an affection of the acoustic nerve, for it has been noticed that a tone may be perceived $\frac{1}{4}$–$\frac{1}{2}$ a tone higher, owing to changes in the tension of the sound-conducting apparatus in affections of the middle ear. Greater differences in perception—as, for instance, to the next third or 1–2 tones higher or lower—may be looked upon as a discordance of the acoustic apparatus; such disorders are very distressing and annoying to musicians, especially if the affection is unilateral, on account of the dissonance of the sound impressions. A false perception for the tones conducted through the air seldom signifies a similar condition for the conduction through the bone.

Diplacusis.—To the false perception for tones it is also necessary to add diplacusis (paracusis duplex), an anomaly of rare occurrence, by which we understand that every sound or only certain tones are heard twice. The author has repeatedly observed this disturbance of hearing in otitis media acuta, in serous middle-ear catarrh, and in chronic middle-ear suppuration; the symptom was transient; in two cases tones as well as speech were doubly heard, and in another case, according to the statement of the patient, they were perceived more as a weak after-tone or echo. Kayser (Berl. Congr., 1890) differentiates a *diplacusis dysharmonica* and *echoica.*[*] In the former, two tones are heard in such a manner that the diseased ear hears simultaneously a higher or lower tone than the normal one. In the second form, as stated above, the sound is perceived later and weaker, resembling an echo.

Cases of diplacusis have been reported by Itard, Sauvages, Beck, Wittich (personal observations), Treitel,[†] Moos and Knapp, who also endeavoured to explain this phenomenon. According to Barth (*Sitzungsber. d. Ges. z. Beförd d. ges. Naturwissenschaften*, No. 7, 1892), to whom we are indebted for his thorough investigations of this subject, diplacusis binauralis may be principally attributed to the middle ear; in such cases the diseased organ does not perceive another tone from that heard by the normal ear, but the same tone at a different pitch. Jacobson does not accept Barth's explanation, and believes that also in middle-ear affections, there is a total or partial discordance of the elastic terminal filaments of the auditory nerve. Gumpert (according to Bressler)

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[*] Cp. Etiévant, *Annal. d. malad. de l'oreille*, etc., 1897.

[†] Cp. Capeder, *Inaugural Dissert.*, Basel, 1895.

describes his personal observation: after an exhausted inflammatory affection of the ear, he noticed a diplacusis. Spoken words were heard as if they came from two different directions. Both words were perceived with an interval between, so that the second was no echo of the first, and he could distinguish them only by the difference in their tones. That he heard double only with the affected ear could be clearly proved by hermetically closing the external meatus of the healthy one.

Paracusis Willisii was discussed under the chronic middle-ear catarrhs (p. 334). **Paracusis loci** does not depend on an anomaly of hearing brought about by a change in the acoustic nerve, but on the difference in the acuteness of perception of the two ears. As our judgment as to the direction whence the sound comes depends on binaural hearing, it is found, especially in cases of unilateral deafness, that the sound will be erroneously interpreted as though coming in the direction of the normal ear (P. Rauge).*

III. Hyperæsthesia Acustica.—This term is used to signify an unpleasant, painful sensation in the ear, which is produced by tones or noises, and which is also found in persons of normal hearing when the highest tones (Galton's whistle, sounding-rods) are elicited near the ear. Anæmic, nervous, hysterical, neurasthenic, easily excitable individuals, and those convalescent after severe illnesses, are often unpleasantly affected by certain tones and noises. This painful perception for noises is a symptom which frequently accompanies hemicrania, trigeminal neuralgia, and a beginning or an already developed cerebral affection. Occasionally it occurs after the internal administration of quinine and the salicylic preparations. Knapp (*A. f. A. u. O.*, vol. ii.) has observed this phenomenon after an attack of sunstroke. Hyperæsthesia acustica is, however, most often met with in acute and chronic affections of the middle ear and labyrinth, especially in the severe forms of otosclerosis. In these cases the sensitiveness to noises is often disproportionate to the disturbance of hearing, as it has frequently been found that when there is complete deafness there is still hyperæsthesia acustica. It not infrequently happens that hyperæsthesia acustica gives rise to a feeling of anxiety, tightness in the head, headache, nervous excitement, and attacks of dizziness.

IV. The Angioneurotic Paralysis of the Acoustic Nerve.—This exceedingly rare affection is characterized by a sudden pallor of the face, nausea, dizziness, tinnitus, and hardness of hearing, which disappear entirely within a few minutes with the return of the former normal colour of the face, and without leaving the slightest disturbance of hearing.

A typical case occurred in the author's practice. The patient was a man, thirty-six years of age, who became deaf in the right ear after an attack of scarlet fever, and in whom the left ear remained entirely normal until six months ago. At that time the patient was attacked by nausea and dizziness, which soon disappeared. The attacks, occurring almost daily since that time, showed the following course according to the description of the patient: with the feeling as though something rushed to his head, pallor of the face and severe

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* Cp. Politzer, *Ueber Paracusis loci* (*A. f. O.*, vol. xi.).

dizziness came on so suddenly that he was compelled to take hold of some object near at hand in order to steady himself; at the same time a loud buzzing sound like that of a steaming kettle, a feeling of fulness, and marked deafness were experienced in the left ear, without the least loss of consciousness during the attack. After several minutes the subjective noises ceased, the face became slightly flushed, the dizziness and tightness of the head quickly disappeared, and the former normal hearing again returned.

The author was able to confirm these statements of the patient by observing the symptoms during an attack. At the moment of greatest pallor of the face, the hearing distance for the acoumeter was found to be over 3 m.; half a minute later it diminished to 1 cm., and the patient could understand only with difficulty words spoken in his immediate vicinity. In two minutes the pallor disappeared, the subjective noises became weaker, and a rather rapid increase in the hearing distance for speech and for the acoumeter was observed. The normal hearing returned five minutes later with the disappearance of the stupor and the feeling of tightness in the head.

As it was assumed that these symptoms were due to an angioneurosis of the acoustic nerve, taking its origin from the sympathetic nerve of the neck, galvanization of the latter nerve was tried. After the application of this current for eight days the attacks did not recur for several days, and by continued treatment for several months, they ceased entirely.

V. Hysterical Paralysis of the Acoustic Nerve.—Peculiar sensations in the ear, such as a feeling of trickling, flowing, and creeping in the deeper portions of the meatus, a painful constriction and pressure in the ear, and an increased sensibility to noises without any perceptible disturbances of hearing, are not infrequently observed in hysterical individuals. One of the most frequent sensory manifestations of hysteria is otalgia,* which, however, may be attributed to hysteria only if, by exclusion of other etiological factors, the rapid change of the neurosis and other hysterical signs point to such an affection (*vide* Otalgia).

It is well known that fainting and general convulsions may be produced in hysterical patients by simple otoscopy, by catheterization, by touching the turbinated bones (Lichtwitz, *Les Anœsthésies Hystériques*, 1887), and by other slight manipulations.

Acoustic anæsthesia†—that is, hypæsthesia—is the most common form of hysterical manifestations of the auditory nerve, and develops as a part of an unilateral hysterical paresis. This form of deafness is more common than was formerly supposed. The disease is characterized by the sudden or gradual appearance of unilateral deafness (seldom bilateral), by a simultaneous, tactile hyperæsthesia, by hyposmia, by a limitation of the field of vision, and by a diminished sensibility to thermic and painful irritations on the affected side. The auricle, the external meatus (Briquet, *Traité sur l'Hystérie*, 1859), and occasionally the membrana tympani and the mucosa of the Eustachian tube of the

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* Gradenigo, *Ueber die Manifestationen der Hysterie in Gehörrgane* (*Haug's klin. Vorträge*, Jena, 1896).

† Ecman, *Un cas de surdité histérique, sans autre manifestation* (*Bull. de la société Belge d'otologie*, Brussels, 1897).

affected side are found to be hypæsthetic. The bone conduction is completely lost.* The tone of a vibrating tuning-fork placed on the vertex is heard in the normal ear; the duration of perception through the cranial bones of the affected side is markedly shortened or completely wanting, so that even the greatest vibrations of the fork at the mastoid process of the diseased side are experienced only as a tactile sensation, in spite of the fact that they are lateralized towards the normal side and must have been perceived as tones. Hammerschlag calls attention to a striking disproportion between the hearing distance for speech and the perception for the tone of the tuning-fork, and considers this as characteristic for hysterical hypæsthesia. While whispered speech is occasionally understood at 2–3 m., the perception for the tone of the tuning-fork conducted through the air is reduced, just as in organic affections of the ear associated with a high degree of deafness. Another symptom observed by Hammerschlag (*Wiener allgemein. med. Zeitung*, 1904) is fatigue of the auditory nerve as the result of continuous stimulation. If a tuning-fork is made to vibrate at its greatest intensity, and is held before the ear until the sound is no longer perceived, it will again become audible after a few seconds, in spite of the fact that it has not been struck again. The diagnosis of hysterical hypæsthesia is made certain if it is possible to influence the hypæsthesia by the phenomenon of transference.

As a matter of interest, we will quote here a few striking examples of hysterical disturbances of hearing, which have been collected from the large number of cases on record.

A girl twenty-five years of age was seized with a gradually increasing left-sided hemiplegia and hemianæsthesia after great mental emotion. The paralysis involved the regions supplied by the trigeminus and occipital nerves up to the median line. The sight in the left eye was lost, and the hearing and conduction of sound through the cranial bones were also gone in the left ear. The sense of smell was lost on the left side, and also the taste on the corresponding half of the tongue. In the further course of the affection, total motor and sensory paralysis was observed in all the extremities and bilateral amblyopia. Sensation and mobility gradually returned, first on the left, then on the right side. Yet, in the following year, the hearing distance was noticed to undergo varying increase and decrease, and at one time a temporary left-sided deafness, amblyopia, hemianæsthesia, absence of galvanic reaction of the auditory nerve, and the phenomenon of transference were observed. Habermann (*Prager med. Wochenschr.*, 1880) reports the case of a boy, fifteen years of age, in whom symptoms of Menière's disease, progressive deafness and blindness, hyperæsthesia of the olfactory nerve, intense headaches alternating with complete apathy and insensibility, hyperæsthesia followed by anæsthesia of the right half of the body, and the phenomenon of transference were attributed to a hysterical affection. A permanent cure is said to have been achieved by the application of pieces of gold to the region of the ear, and by the internal administration of chloride of gold.

A sudden complete return of the hearing power, after a deafness of eleven

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* Lannois et Marc' Hadour, *Ann. des malad. de l'oreille*, etc., 1899.

months following a concussion of the skull, was observed by the author in a man twenty-one years of age.

Hammerschlag observed a similar case in an old woman, who became completely deaf in the left ear after a fall, and in whom normal hearing, accompanied by a loud snap in the ear, suddenly returned on the third day. Veit (*Münch. med. Wochenschrift*, 1898) treated a young man, twenty-six years of age, who, upon awaking one day, found that he was deaf and dumb; after a single catheterization the hearing and speech again returned. Attacks of temporary deafness, with vicarious hæmorrhages from the ear, have been observed by Stepanow, Benni, Eitelberg, Ferreri, and Gradenigo.

Tinnitus and attacks of dizziness do not belong to the symptoms of true hysterical hypæsthesia. The occurrence of these phenomena in hysterical persons must be regarded, according to Hammerschlag, as a sure indication of an organic affection of the ear. That, in hysterical individuals even slight aural affections may produce severe disturbances of hearing, which are rapidly relieved by local treatment, is known to every specialist.

The sudden changeable character of hysterical deafness explains the brilliant results which have been obtained by the various therapeutic procedures. While some observers praise the favourable effect of the electric treatment, others highly commend the treatment by transference, by metallo-therapy, and by hypnotic suggestion. It has been shown that the last of these, produces an immediate striking improvement in the hearing in some cases. This, however, is the only form of disturbance of hearing in which it is permissible to employ hypnotism. Its application in other forms of disturbance of hearing and for subjective noises has proved utterly useless.

In addition to the forms of paralysis of the acoustic nerve detailed here, other paralyses of this nerve (such as a rapid loss of function in one or both ears) are sometimes observed, in which the objective examination is negative; these paralyses, however, cannot be classified with any form of disease described so far, on account of the absence of any apparent etiological factor, and the want of other accompanying symptoms, as subjective noises, dizziness, and disturbances of equilibrium. Whether we have to do in such cases with true anatomical changes, or only with a functional paralysis of the acoustic nerve, cannot be determined owing to the lack of anatomical data. The rapid disappearance of the disturbance of hearing would in some cases point to a true functional disorder. Bloch (*Deutsch. Otologentag*, 1906) found a nerve deafness of varying degree in seven out of eight cases of retinitis pigmentosa.

Attention must still be called to a form of disease, which might be designated sympathetic paralysis of the auditory nerve. It has already been shown that in unilateral aural affections associated with a high degree of deafness, disturbances of hearing develop more or less rapidly in the other ear which was previously in a normal state. From the absence of objective

symptoms in the sound-conducting apparatus, and from the results of the tuning-fork tests, it may be concluded with absolute certainty that we are dealing in these cases with an affection of the acoustic nerve. We are still at a loss to explain the anatomical conditions which cause this sympathetic affection of the auditory nerve.

It would be going too far, however, if, in unilateral disturbances of hearing, a later affection of the normal ear should always be regarded as of sympathetic origin. In many cases of so-called sympathetic affection we are certainly dealing only with an ear which has been previously diseased, and not with an organ which has become pathologically altered by direct influence from the diseased ear. A reaction of the diseased ear upon the normal one may be clinically shown only in cases of marked hardness of hearing or total deafness; experience has demonstrated that in these cases the predisposition of the normal ear to become diseased increases as the hearing power of the affected ear becomes worse. Whether this condition is due to pathological changes extending from the auditory nerve of the diseased ear to the acoustic nucleus and roots of the other, or normal one, is difficult to say, and must be decided at some future time by clinical observations supported by the conditions found at the *post-mortem* examination.

The assumption that the simultaneous appearance of ocular and aural affections is due to a relationship between the eyes and ears must be contradicted, as affections of both of these organs usually can be traced to the same etiological factor (atmospheric influences, scrofula, acquired and hereditary syphilis, etc.). The disturbances of vision, which are often associated with catarrhal and inflammatory aural affections, are not to be looked upon as due to any particular relationship between the ears and eyes, as temporary changes in vision may be brought about reflexly, or may be due to an affection of some other organ or other part of the body. The assumption that a disturbance in hearing may be followed by a diminution in vision of some duration is erroneous. If the disturbances in hearing had such an influence on the eye, disturbance of vision would occur much oftener than is really the case. We only need to refer to the known fact that the majority of deaf-mutes possess a sharp vision, and that likewise the majority of blind persons have an acute hearing.

The Treatment of Paralyses of the Acoustic Nerve.—The treatment of paralyses of the acoustic nerve depends on the cause and duration of the affection, on the degree of disturbance of hearing. and on the accompanying symptoms. In recent cases it is advisable to keep the patient in a quiet room for several days, and not to employ any local treatment of the ear. In several cases of hardness of hearing which came on suddenly, the author effected a striking improvement by subcutaneous injections of a solution of muriate of pilocarpin (4–10 drops of a 2 per cent. solution for eight to ten days). Dundas Grant (*Brit. Med. Journal*, 1895) and Schirmunsky (*M. f. O.*, 1895) confirm the favourable results of the pilocarpin treatment in acute cases. In cases in which pilocarpin proved ineffectual, sodium iodide ($\frac{1}{2}$ gramme pro die) was administered with good effect.* Purgatives, stimulating foot-baths, alcoholic embroca-

* Sajodin in pastilles (0·5), two to three a day, has lately been recommended.

tions, and vesicants to the mastoid process, as well as diaphoretics, occasionally prove very beneficial. If the paralysis is due to some syphilitic lesion, as is demonstrated by the result of the Wassermann test, a rigid antisyphilitic treatment should be given, and in the majority of cases the lost or impaired hearing will gradually return to normal.

The chances of improvement are less the longer the disturbance of hearing continues. Experience, however, shows that even in cases of long standing a satisfactory result may sometimes be obtained by proper local and internal treatment. For local treatment the following are recommended: injections of a solution of muriate of pilocarpin through the catheter into the tympanic cavity (4–8 drops of a 2 per cent. solution for ten to twenty days), injections of a solution of potassium iodide (0·5 : 20·0, 10–15 drops) when the condition is of a syphilitic nature, and, lastly, the introduction of the vapours of acetic or sulphuric ether (pure, or mixed with half-pure liquid ammonia) into the tympanic cavity *per tubam.* In disturbances of hearing of a nervous nature, which are not associated with subjective noises, endermic embrocations of strychnine (0·1 : 20·0 glycerine, 6–8 drops) on the mastoid process may be tried. The local treatment may be facilitated by the internal administration of potassium or sodium iodide (0·5 pro die) or strychnine (0·07 : 20·0 aqu. destil., t.i.d. 3–5 drops). If these various remedies prove ineffectual, it is advisable to resort to the galvanic treatment.

Subjective Sensations of Hearing.*—Subjective noises in the ear, which are always symptomatic of an irritation of the auditory nerve, or of its terminal filaments in the labyrinth, are produced either by affections in the ear itself, or by reflex irritations of the cranial and spinal nerves.† They constitute a very frequent, sometimes an almost unbearable, symptom of affections of the ear, the significance of which has been repeatedly pointed out in describing the Symptoms of Diseases of the External, Middle, and Internal Ear. (See those chapters.)

In the great majority of cases subjective noises are localized in the ear itself, but in many instances they are experienced within the head, in the occiput, in the temporal region, or on the vertex. Intense noises, which occur in paroxysms, often extend from the ear to the inner portion of the head, and spread sometimes to the frontal and sometimes to the occipital region. It rarely happens that the sensation of sound is projected outwards. This is especially the case, however, in the beginning of the affection, when the subjective sensations are erroneously

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* Cp. the exhaustive paper by the author, *Ueber subjective Gehörsempfindungen* (*Wien. med. Wochenschr.,* 1865).

† Trétrôp (*Congr. de la Soc. franc. de laryngol.,* etc., 1906) observed subjective noises as the first symptoms of an aneurism of the middle meningeal artery.

mistaken for objective noises, until experience corrects this pheno-
menon and rectifies the false conception.

The subjective sensations of hearing are most frequently ex-
perienced as whizzing, roaring, buzzing, seething, hissing tones,
ringing, humming, and whistling in the ear. They are desig-
nated as low or high by the patients.* They are often compared
to the noise of a railroad train, the chirp of a cricket, the warble of
birds, or to the rarest kinds of noises, as, for instance, the hearing
of inarticulate human voices, the barking of dogs, the crashing
of plates of glass, the grinding of scissors, the cracking of beams,
the sound of trumpets, the tone of a low or high string of a
violin, chaotic musical tones, creaking and crackling, pistol
shots, rustling noises, the sensation of wind rushing from the
ear, the blow of a hammer, the noise of a mill, the croaking of
frogs, etc. Objective noises (as, for instance, the tick of a
watch) are often not recognized as such if they are similar to the
subjective noises of the patient. A patient who said that he
constantly heard the chirp of a cricket was not able to recognize
the chirp which the author imitated with his mouth in the
patient's immediate neighbourhood, in spite of the fact that the
deafness was of a slight degree. Frequently, only one kind of
subjective noise is heard; occasionally, however, it changes, and
the most varied kinds of noises are perceived simultaneously.
The intensity of the subjective noises is seldom uniform; it
usually shows marked variations, depending on the diseased
process itself, but more often on external influences or somatic
conditions.

The following may be mentioned as some of the external
influences which produce an increase in the subjective noises:
Changes of weather and temperature, great heat, wind, draughts,
rainy, damp weather, and confinement in close, damp, or smoky
rooms. The noises are generally less annoying in the open air.
Marked tinnitus is often not noticed on account of diversion and
occupation, which explains why many persons do not hear the
noises during the day, while they become distinctly audible
when the external auditory canal is closed, in quiet rooms, and
at night before going to sleep. Marked objective noises often
overshadow the subjective ones so completely that persons in
waggons, in the train, and in noisy rooms do not perceive their
intense ringing in the ears; this, however, makes the latter appear
so much the louder when the environment becomes quiet again.
The author has frequently seen persons who still heard subjective
noises in the midst of the greatest uproar. That marked objec-
tive noises may temporarily diminish the subjective sensations

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* According to Panse (*Zeitsch. für Ohrenheilk.*, 1898), subjective sensations
of hearing of a high pitch are always brought about by changes in the laby-
rinth or in the auditory nerve, or by reflex irritation.

of hearing was already known to the older authors (Plater, Itard); one sometimes notices in aural patients that the noises are lessened, or made to disappear entirely for a short time (Urbantschitsch), by the action of the tone of a tuning-fork on the ear.

Bodily and mental exertions, affections of the mind, continuance in a stooping position, excessive talking, coughing and sneezing, movements of the jaw in chewing, turning and shaking the head, sleeplessness or too much sleep, the use of alcoholic beverages, smoking, overfilling the stomach, indisposition, diseases, menstruation, pregnancy and parturition, and, in fact, all things which tend to produce an irritation to the nervous system usually increase the tinnitus in an astonishing manner. Noises, which are not even very intense, are especially annoying to hysterical and neurasthenic individuals. Children seldom complain of subjective noises.

Subjective noises become more endurable when the body is in a healthy condition, when the mind is at ease, in individuals who have a happy disposition, and in dry, clear weather.

Subjective sensations of hearing may be either intermittent or continuous (*vide* p. 176). The continuous noises may either begin as such or they may develop from the intermittent ones, inasmuch as the intervals, which were considerable at the beginning, gradually disappear altogether.

In some patients they produce such unbearable torture that the patients are driven to suicide. Others gradually become accustomed to them. Subjective noises which arise with a typical regularity are rare, and have generally been observed in intermittent fever.

The relation of subjective noises to disturbance of hearing has been discussed in the various forms of diseases of the ear. It must still be mentioned, however, that in a number of cases the intensity of the noises increases with that of the disturbance of hearing; in others they cease with the deafness; in other cases, again, they continue to increase after the loss of the hearing. Attention must still be called to the fact that those diseases of the labyrinth and auditory nerve which are often most severe clinically may run their course without any sub-jective noises.

' Nervous tinnitus,' or ' ringing in the ears without difficulty in hearing,' is that form of tinnitus which must be looked upon as a pure neurosis. It occurs mostly in nervous persons, after severe mental exertions, from grief, in exhausted conditions, with anæmia, after parturition, after a severe concussion of sound. and occasionally also in persons who are in a perfectly normal state of health. Co-existent sensitiveness to light and disturbances in other nerves point towards a central affection. The patients most frequently complain of ringing. hissing. and

buzzing in the ear; still, the noises seldom reach such an intensity as those accompanying chronic adhesive processes of the middle ear.

Nervous tinnitus may disappear sooner or later, but not infrequently it continues during the whole life of the patient without any disturbance of hearing. Sometimes, after a long observation, it proves to be the forerunner of otosclerosis or of a cerebral affection.

Subjective sensations of hearing are occasionally produced reflexly from the trigeminus, less often from the facial nerve; they are also experienced in cases of neuralgia and hemicrania. They must be looked upon as reflex symptoms if they arise during an attack of neuralgia, and again disappear after the attack has passed away. The author has repeatedly noticed that subjective noises may also be produced and existing sensations of hearing increased or diminished by irritation of the skin in the region of the ear which is supplied by the trigeminus nerve; such irritations may be occasioned by stroking the skin or by shaving. In a musician who was under the author's observation, the sensation of certain musical tones could be produced by stroking the skin at the external auditory orifice and by an act of swallowing.

Hallucinations of sound (articulate human voices, musical melodies) are rarely met with in individuals with an aural affection, unless it be complicated by an altered condition of the brain. Clinical experience has shown* that hallucinations arising from a cortical lesion become worse by the intercurrence of an affection of the ear, and that in some psychoses the hallucinations may be diminished or removed by a successful treatment of the aural affection.

According to the author's observations, the subjective sensation of sound experienced by aural patients whose mind is in a normal condition, is that of musical melodies which constantly repeat, and which often make the individuals disgusted with life. Thus two young English ladies constantly heard the melody of ' God Save the Queen.' In the one, the sensation disappeared after several weeks' treatment of a middle-ear catarrh. A man of advanced age, who had become moderately deaf in consequence of otosclerosis, sought relief for an annoying Ambrosian church song which had continued uninterruptedly for months, and which he had not heard since his school-days. The subjective sensation of articulate human voices (entire sentences) has a more unfavourable prognosis, and often appears as the forerunner of a severe psychosis (melancholia, progressive paralysis). Those cases in which hallucinations are produced by a ceruminous plug or foreign body in the ear are of very rare occurrence.

* Köppe, *A. f. O.*, vol. ix.

The statement that hallucinations of sound are found in the various forms of psychosis, and are produced by a simultaneous affection of the ear, is corroborated by the thorough investigations of Redlich and Kaulmann (*Wien. klin. Wochenschr.*, 1896), who examined a large number of persons having a mental affection (paranoia, melancholia, mania, delirium tremens). It was found that in a great percentage of the cases visible pathological changes were present in the external, middle, and internal ear.

Combinations of tinnitus, hallucinations, and epileptiform attacks, as seen in a case reported by Fleury (*Ann. d. malad. de l'oreille*, etc., 1900), are rarely observed (Lannois, *Epilepsia ab aura læsa*). In a case reported by Pick (*Jahrb. f. Psychologie*, 1890) of right-sided epilepsy and hallucinations of sound on the corresponding side, the autopsy revealed a lesion of the left cerebral hemisphere.

Prognosis of Subjective Sensations of Hearing.—The prognosis of the subjective sensations of hearing depends on the cause and duration. Those noises which are occasioned by diseases of the external ear, by acute inflammations of the middle ear, and by exudative catarrhs, have, as a rule, a favourable prognosis. It is unfavourable in otosclerosis, in the severe forms of labyrinthine diseases, in disturbance of hearing of cerebral origin, and in the arterial noises in the ear which have existed for a long time. The prognosis of intermittent subjective noises is favourable, while that of continuous noises is unfavourable.

Treatment.—In the treatment of subjective noises it is of the greatest importance to ascertain the cause. The subjective sensations of sound usually disappear after the removal of ceruminous and epidermic masses, granulations, and polypi from the external ear. In like manner the noises produced by an abnormally increased pressure in the labyrinth, as is often observed with impermeability of the Eustachian tube, and with accumulations of mucus, pus, and masses of epidermis in the tympanic cavity, will frequently disappear entirely after the removal of these pathological conditions. The same applies to the subjective sensations occurring during the course of an acute inflammatory process in the external or middle ear, or from anomalies of tension in the sound-conducting apparatus. On the other hand, treatment proves ineffectual in the majority of cases in which the continuous noises are caused by the formation of new connective tissue in the tympanic cavity, by otosclerosis, by an impermeability of the Eustachian tube, and in those cases in which they are associated with an affection of the labyrinth and a diseased condition of the brain. This is found to be especially the case when the noises have lasted for months or years.

The effect of local treatment on subjective noises in chronic affections of the ear cannot be foretold. In some cases the noises

cease entirely, in others they become weaker, and in the majority of cases they remain unaltered even when a marked improvement in the hearing has been obtained. After treatment for some time the diminution in the noises is sometimes permanent; more often, however, there is a gradual increase even after treatment for several weeks or months. If the treatment is continued too long, it may intensify slight noises, and may even in some cases produce them.

As in the great majority of cases subjective noises are an accompanying symptom of an inflammation, catarrh, or adhesive process of the middle ear, the treatment is essentially the same as the treatment of the local affection causing them. When there are accumulations of secretion in the middle ear, or anomalies of tension in the sound-conducting apparatus which bring about an increased pressure in the labyrinth, it has been found that inflations of air into the middle ear and rarefaction of the air in the external meatus are often the most effectual means by which these subjective noises are overcome. The effect is most noticeable immediately after such treatments, inasmuch as the severe noises often cease promptly, or become markedly diminished. This result is more permanent after the application of the author's method of inflation, combined with rarefaction of the air in the external meatus, than after catheterization, unless there is a stricture of the tube, in which case the use of the catheter and bougie is indicated. Inflations of air, combined with vapours (p. 125) of sulphuric ether, acetic ether, chloroform, or of a mixture of equal parts of other sulphuricus and ether chloratus, of iodide of ethyl, and, finally, of the spirits of nitrous ether, have proved of value to the author. After catheterization and injection of 8–12 drops of a 1 per cent. solution of pilocarpin hydrochlorate, or 10 drops of a solution of sodium bicarbonate (0·5 : 10·0), there is sometimes a diminution in the subjective noises, and an increase in the hearing distance.

The application of counter-irritants and vesicants behind the ear, which was formerly highly recommended for tinnitus, is of little value, and no longer used. The author has found counter-irritation on the mastoid process somewhat useful in cases in which the noises are of recent standing, and in patients in whom the continuous tinnitus has increased to an unbearable degree. Alcoholic embrocations on the mastoid process,* or the application of a cantharides plaster, sometimes produce a marked relief.

In cases in which the subjective noises were of recent date, the author has diminished their intensity by the application of bisulphate of quinine to parts of the mastoid which had been exposed by vesication.

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* R.: Spiritus aromatici, spiritus sinapis, ana 30·0. Sig.: Rub 20 drops behind the ear.—R.: Spiritus formicar., balsam. Hofmanni, ana 30·0. Sig.: Use as above.

Narcotic embrocations in the region of the ear* seldom prove of value.

Instillations of narcotic oils into the external auditory canal often increase the subjective sensations of sound, and decrease the hearing, inasmuch as the oily substances dry on the membrana tympani and form a thick layer upon it. On the other hand, however, an alleviation of the tinnitus and a subjective feeling of relief are often brought about by painting the cartilaginous meatus with a medicated glycerine solution, especially when the meatus is dry and void of secretion. In the author's practice he uses the following solutions: R.: Tincturæ ambræ 2·0, etheris acetici 1·0, glycerini puri 25·0. R.: Tincturæ valerianæ 2·0. etheris acetici 1·5, glycerini puri 30·0.

Of all the internal medicaments, sodium bromide (1–2 grammes daily) has proved especially beneficial in those cases of nervous excitement and sleeplessness which have been brought about by intense subjective noises. Hydrobromic acid (10–30 drops t.i.d. in sweetened water), as recommended by Woakes, seldom produces a noticeable diminution in the subjective sensations of sound. Lucae recommends isopral 0·5 pro die.

In otosclerosis, and in the aural affections secondary to constitutional syphilis, a diminution in the subjective noises is sometimes observed after the internal use of potassium iodide (0·5–1·0 daily). In some cases of syphilitic origin the intravenous injection of salvarsan has proved beneficial. The effect of the general and internal medication may, in the latter cases, be increased by inunctions of an iodide (potassium iodide 2·0, pure iodine 0·2, lanolin, vaselini ana 15·0) ointment on the mastoid process.

When the noises are of a pulsating character, with or without an affection of the heart, the author has repeatedly seen them strikingly diminished by the internal administration of tincture of digitalis (6–10 drops), or of tincture of strophanthus (5 drops t.i.d.). Dundas Grant (*Brit. Med. Journal*, 1887) recommends compression of the vertebral arteries for pulsating noises in the ear. Curetting the vestibule of the labyrinth in order to overcome the severe tormenting noises of otosclerosis, as performed in one case by Matte (*Deutsch. med. Wochensch.*, 1906), is admissible only in very desperate cases. Lake, Parry, and Milligan report variable results in cases in which the labyrinth was opened for marked deafness, dizziness, and subjective noises. Whether in cases of severe tinnitus it is justifiable to open the cranial cavity and to sever the root of the auditory nerve, as has been carried out by Wallace and Marriage in one case with a fatal

* R.: Glycerini puri 10·0, extract. laudani aquos, 0·4. M. tere exactissime D.S.: 8-10 drops to be rubbed behind the ear.—R.: Glycerini puri 10·0, acetat. morph. 0·2. M.D.S.: Same as other.—R.: Olei olivarum, chloroform., ana 8·0. M.D.S.: Same as other.—R.: Glycerini puri 10·0, tinct. belladonnæ 5·0. M.D.S.: As above.

termination, is a question which must be decided by future experiences.

Change of climate, a sojourn in an elevated resort, and the use of medicated and iodide baths not infrequently have a favourable effect on subjective noises. In cases in which there is a co-existing intestinal disorder, the subjective noises are often markedly alleviated by drinking mineral waters containing salts, which have a purgative effect upon the bowels.

A suitable diet, a regular life, the avoidance of bodily and mental exertion and loud noises (loud music, noise of a factory), and a limited use of alcoholic beverages and tobacco, have a decided beneficial influence on subjective noises.

The electric treatment of subjective sensations of sound will be discussed in following chapters.

The so-called entotic noises must be differentiated from subjective sensations of hearing, inasmuch as the former are due to the objective perception of a noise arising in the ear itself, or in its immediate neighbourhood These are experienced as cracking noises in the cartilagino-membranous portion of the Eustachian tube, brought about by a contraction or chronic spasm of the muscles of the tube itself, as mucous and rattling noises, and as ticking or humming sensations produced by the voluntary or involuntary contractions of the intrinsic muscles of the ear (p. 633). The vascular noises are the most common; they are caused by a dilatation of the arterial vessels in the tympanic cavity, or by changes in the carotid canal; or they are transmitted to the ear in valvular lesions, goitre, aneurisms of the arteries of the head, or of the external carotid (Alt), with a *bruit du diable*, or with a dilatation of the vessels of the head supplying the ear. In the last case the noises, which are usually·of a blowing character and synchronous with the pulse, can be heard at all parts of the head by auscultation. Brandt was able, in one case in which objective vascular noises spread over the entire head after an injury, to effect a cure by ligating the deep temporal artery (*W. med. Bl.*, 1888). Goldflamm and Meyerson (*Wien. med. Presse*, 1895) reported a case in which a noise in the ear, caused by an angiosarcoma, could be heard objectively; Gomperz also reported a case in which the bruit took its origin from the veins of the neck, and could be heard objectively in the ear.

The results of ligating the carotid artery in order to relieve entotic noises have, up to the present time, been rather unsatisfactory. Münch reported a case which was cured by this operative procedure (*Z. f. O.*, vol. xxxii.); Meyerson (*Vers. d. deutsch. Naturf. u. Aerzte*, 1895) and Grunert, however, reported cases (*A. f. O.*, vol. xxxv.) in which the noises returned after four hours and four months respectively.

In a case of Linsmayer's, the noises ceased only for a short time after ligation of the carotid artery; hemiplegia of the left side, with hemianopsia and deafness of the same side, ensued shortly thereafter, and five days later the patient died of pneumonia. The autopsy showed extensive softening of the right cerebral hemisphere, which had existed only a short time.

The Electric Treatment of Functional Disturbances of the Internal Ear by means of the Constant Current.—In giving this treatment we generally use the galvanic current, which is obtained

from a well-constructed electric switchboard or wall tablet. This is supplied with a rheostat with which we can regulate the strength of the current. In addition to this there is a galvano-meter and a commutator, by means of which one is able to reverse the direction of the current. This also allows one to elicit the voltaic alternatives, which can be used for diagnostic and therapeutic purposes.

There are three methods by which the current can be applied: (*a*) The internal application. in which the external meatus is filled with a weak saline solution into which the electrode is inserted; (*b*) the external application, in which the moistened electrode is placed against the lobule or margin of the external auditory orifice; (*c*) galvanization by means of an electric probe introduced into the Eustachian tube. The author generally employs the second or external method, as the repeated intro-duction of fluid into the external meatus gives rise to an in-flammatory irritation.

The action of the galvanic current on the auditory nerve depends principally on the intensity of the current (average $\frac{1}{2}$ to 2 milliampères), and on the susceptibility of the individual. In addition to these, however, many local conditions, such as abnormal dryness and moisture, hyperæmia or anæmia of the parts, conditions obstructing the conduction of the waves of sound in the ear, as ceruminous, purulent, or fluid accumulations, and, furthermore, the state of the membrana tympani and tympanic cavity, play an important part in this method of treatment, inasmuch as the current is greatly influenced by these obstacles. Finally, it must be borne in mind that the irritability of the normal acoustic nerve varies within certain limits, according to the intelligence and comprehension of the patient.

If the acoustic nerve reacts to the electric current, there is experienced a sensation of sound, which, however, varies in different individuals (ringing, whistling, hissing, etc.). The electric dizziness, which occurs during galvanization of one ear, more often, however, when the current is conducted directly through the head, is produced by irritation of the vestibular apparatus in the labyrinth (electric vertigo, see p. 170).

The following may be mentioned as symptoms accompanying electric irritation of the organ of hearing: Pain and burning sensation in the external meatus (trigeminal irritation), con-tractions of the muscles of the face (facial irritation), formica-tion, sensations of taste in the tongue, acts of swallowing, saliva-tion, and photopsia (irritation of the terminal filaments of the optic nerve). When these symptoms occur during galvanization of the ear, the electric current must be reduced immediately.

According to Brenner, the normal auditory nerve always reacts to the galvanic current, and even in a definite manner with sensations of sound, which regularly appear with a certain strength of the current, and which

have a fixed relation to its direction—that is, to its opening and closing. These facts were employed by that author to establish the law for the electric reaction of the normal acoustic nerve.

Brenner's law is as follows: When the cathode (Ka) is introduced into the external meatus, a sensation of sound (K[1]) is produced at the closure of the circuit (S), which lasts (D) during the closure, and ceases again at the opening (O). If the anode (A) is introduced into the meatus, no reaction is experienced either at the close or during the continuance of the closure of the circuit; but, upon opening, a weak sensation of sound is produced.

Pollak and Gaertner (*Naturforscherversammlung, Köln*, 1888), and at the same time Gradenigo (*A. f. O.*, vol. xxvi.), have shown that an acoustic reaction is seldom obtained with a current of medium intensity (to 6 milliampères) in persons whose hearing is in a normal condition, while a sensation of sound is very often experienced with a similar current in individuals who have a pathological condition in their organ of hearing. Pollak and Gaertner furthermore demonstrated that in cases in which there is an exudative process in the ear (secretory forms of inflammation), the power of resistance to the current is lessened by the fluid, so that the auditory nerve can be made to react even with very weak currents (1–2 milliampères). They therefore concluded that the conditions within the ear have an important bearing on transmitting the current, and on the production of the electric sensation of sound. Gradenigo's view differs in so far that he attributes the increased electrical reaction of the acoustic nerve to a heightened irritability induced by the pathological process. He agrees with v. Frankl-Hochwart that it is observed not only in catarrhs and inflammations of the middle ear, but also in otosclerosis, in endocranial diseases, and in other affections of the acoustic nerve due to anatomical changes.

Galvanization of the ear has also been recommended for diagnostic purposes in order to ascertain whether there is an increased (hyperæsthesia) or decreased (torpidity) irritability of the auditory nerve. The diagnosis of hyperæsthesia of the acoustic nerve is established when a reaction is obtained even with very weak currents; on the other hand, it may be concluded that there is a torpor of the nerve if no subjective sensations of sound are elicited, notwithstanding the application of currents which are strong enough to produce contractions of the muscles supplied by the facial nerve. The hearing power has no bearing on the electric irritability, as the latter may be present even if there is total deafness.

Galvanization of the ear is carried out in such a manner that the anode is used as the electrode for the ear, while the other electrode is applied to some other part of the body, as, for instance, the palm of the hand or the nape of the neck. To estimate the irritability of the auditory nerve, we employ a gradually increasing constant current in order to ascertain the weakest current by which the nerve is made to react. Only

weak, gradually increasing currents should be used in the treatment of subjective noises. In addition to the method of treatment with open and closed currents, the voltaic alternative may also be used (repeated change of current) in some cases as a therapeutic measure (Benedikt, *Wien. med. Presse*, 1870). We cannot lay down any positive indications as to the method to be employed, as sometimes the voltaic alternatives prove effectual where the open and closed circuit fails, and *vice versa*. In every case, therefore, the application of one or the other methods must be tried in order to see which proves most beneficial.

Opinions of otologists vary as to the curative action of the galvanic current on the organ of hearing. J. Pollak is supposed to have seen striking results from galvanization of the auditory nerve, while other observers believe that it has no lasting influence upon the hearing and subjective noises. The author's experience on this subject shows that permanent improvement in the hearing and complete removal of the subjective noises are obtained in only rare cases by the galvanic treatment; yet it not infrequently brings about a diminution in the intensity of the subjective sensations of sound and a marked improvement in the head symptoms (heaviness, pressure, dizziness, stupor) which so often accompany aural affections. Agreeing, however, with other observers, it must be stated that the galvanic treatment occasionally causes an aggravation of the symptoms, in that the subjective noises become more intense, and a marked general irritability is noticed in the patient, even after a few sittings.

Injuries of the Internal Ear.

Injuries of the internal ear arise either from direct or indirect violence. Under the former we must consider those in which a foreign body (sharp instruments, projectiles) enters the external meatus, and after penetrating the membrana tympani forces its way into the cavity of the labyrinth.

Traumatic affections of the internal ear due to indirect violence are of more frequent occurrence. They are divided into two groups. The first comprises injuries caused by the immediate action of violence upon the bones of the head, and by transmission of the shock to the internal ear. The second includes those concussions of the terminal filaments of the nerve produced by a sudden condensation of the air in the external meatus, or by the action of an intense sound upon the ear.

The force applied to the cranial bones may injure the internal ear in two ways: (1) by extension of a cranial fissure to the petrous bone; (2) by transmission of a concussion to the labyrinth without actual injury to its capsule.

Following an injury of the skull, an osteomyelitis of the cranial bones may develop through infection, and thus produce an injury to the organ of hearing (Laurens, Schilling, Guisez*).

Fissures of the petrous bone, complicated with injuries of the skull, are usually associated with fissures of the tympanic cavity and external auditory canal. For further details in reference to these injuries, which are combined with severe hæmorrhages, discharge of serous fluid, tinnitus, dizziness, and deafness, the reader is referred to the chapter on Injuries of the Sound-Conducting Apparatus (p. 634).

The following two cases observed by the author will serve as illustrations:

The first case was that of a man, forty years of age, who had fallen upon his occiput, became totally deaf with symptoms of tinnitus, dizziness, and disturbances of equilibrium, and died seven weeks after the injury, with symptoms of meningitis. The autopsy showed a ragged fissure of the occipital bone, which extended through both labyrinths, and ended close to the inner wall of the tympanic cavity. The cavity of the left labyrinth was filled with a dark red mass resembling a coagulum of blood; the right labyrinth contained a purulent, broken-down extravasate which had forced its way from here into the internal auditory meatus, and caused a fatal basilar meningitis. No sign of an injury was perceptible on the dura mater.

In the second case observed by the author† a tub containing mortar fell upon the head of a man twenty-one years of age while working in a building, whereupon he became senseless. It was fourteen days before consciousness returned; he was totally deaf, his gait was uncertain and staggering, and a right-sided facial paresis was noticed. In the fifth week after the injury symptoms of diffuse leptomeningitis arose, which caused a fatal termination after five days. The autopsy revealed a purulent meningitis and fissure of the base of the skull, which extended through both petrous bones as far as the inner wall of the tympanic cavity. The histological examination of the right ear showed that all the windings of the cochlea were filled with round sells and with a fine granular exudate, and that the utricle, ampullæ, and semicircular canals were also filled with masses of exudate (Fig. 291). The perilymphatic space of the semicircular canals (*e'*, *e''*) was partly filled by the inflammatory swelling of the connective-tissue layer. In the left labyrinth a connective-tissue growth was found, which arose from the endosteum of both scalæ of the cochlea, and which increased in size towards its axis. Corti's organ was disorganized by the growth of epithelium.

Hennebert reports cases of stab-wounds of the internal ear (*Journ. de Méd. et de Chir.*, 1892), having observed one with a fatal meningitis, and two with incurable deafness. Kayser (*M. f. O.*, 1895) reported a case in which the labyrinth was undoubtedly injured, and in which the hearing was completely restored; Brieger (*Klin. Beiträge*, 1896) describes a case of injury to the labyrinth, with the discharge of perilymph, which was associated with dizziness, tinnitus, and a high degree of deafness.

During the last few years our methods of examination of the ear have been augmented by the addition of X-ray radiographs. The author was himself able, by means of the X ray, to locate the seat of a revolver bullet in the temporal bone. According to Leidler and Schüller,‡ it is possible by proper

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* *Arch. internat. de laryng., d'ot., et rhin.*, part xxii., No. 1.

† *Menière'scher Symptomencomplex in Folge traumatischer Labryinthläsion* (*A. f. O.*, vol. xl.).

‡ A. Schüller, *Die Schädelbasis im Röntgenbilde* (Hamburger Atlanten, 1905); Leidler and Schüller, *Demonstration. Sitzungsber. der österr. otol. Ges.*, March 30, 1908.

exposures to the X ray to distinguish a number of pathological changes in the temporal bone. For this purpose it is well to make exposures in the following three directions:

1. Exposure through a frontal section, whereby the median plane of the head lies parallel to the photographic plate, and the Röntgen tube being 60 cm. from the plate, stands over the external auditory canal. In the second exposure, through a sagittal section, the occiput lies on the plate, and the tube is over the face of the patient, so that the rays pass through the middle point of the line of communication between the two external auditory canals. These two exposures serve as a survey by which we can tell the general relations of the base of the skull. In order to get a view of the details of the temporal bone, the following (third) exposure is the best: the head is tilted, whereby the head, with the auricle, rests against the plate, while the X-ray tube is placed over the parietal eminence of the opposite side. On this radiograph one sees the triangular shadow of the petrous bone, bounded dorsally by the projection of the superior angle of the pyramid, and behind by the contour of a bright area which corresponds to the sigmoid sinus. At the base of this bright area one sees the net-like demarcations of the mastoid cells well defined, while ventrally one sees the bow-shaped contour of the processus mastoideus and the
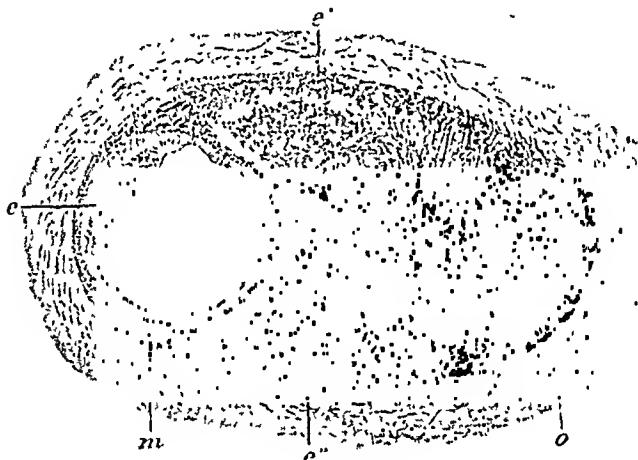
FIG. 291.

incisuia jugularis. Within the dark shadow of the pyramid two circular light areas are distinguished, of which the larger corresponds to the external, the smaller to the internal meatus, and which probably also take in the vestibule.

The following pathological processes require a Röntgen examination: 1, foreign bodies (projectiles); 2, injuries (fractures at base of skull); 3, malformations; 4, hyperostoses; and 5, destruction of tissue (through inflammatory processes, cholesteatoma, sequestra, or tumours). In the last mentioned it is especially important to ascertain their size and location, and, furthermore, to know whether they have extended to the dura of the middle or posterior cranial fossa (that is, to the sinus). By means of the X-ray examination one can usually ascertain the anatomical structure of the mastoid process, as it enables one to determine beforehand whether we are dealing with a pneumatic or diploëtic bone, and, furthermore, it informs us as to the location of the sigmoid sinus in a large number of cases. This method is also of value in aiding us to determine the pathological condition of the mastoid bone, particularly in those cases in which the clinical diagnosis points to an abscess formation. When the plates show a cloudiness of the cells or an obliteration of the intracellular elements, one may assume with great probability that one is dealing

with a mastoid in which the tissue has broken down and has developed into a true mastoiditis. It is a fact that with the advance of X-ray therapy our methods of diagnosis have been greatly improved, and that the Röntgen examination has proved-of value in mastoid work, yet one must not place too much reliance on such findings, as they are often unreliable and very mis-leading. If taken in conjunction with our clinical symptoms, the X-ray picture is frequently of great assistance in clearing up a doubtful diagnosis. In taking an X ray of a suspected unilateral mastoiditis, one must also take a picture of the other or healthy side, and by comparison note the presence of any pathological changes, as it is only by this means that one can at times come to a positive conclusion. The correct interpretation of the X-ray picture is often difficult, and is influenced by several important factors. In the first place, the structure of the bone itself has a direct bearing on the picture, as a hard ebonized bone will often cast a dense shadow, which may be mistaken for a destructive process and give a false impression that one is dealing with a true mastoid abscess. In the second place, an inflammatory swelling of the lining membrane of the mastoid cells, whereby the small cell spaces are more or less obliterated, with or without the presence of a serous exudate, often produces a cloudiness on the plate, and may also give one the impression of a mastoid abscess. It frequently happens that the X-ray picture reveals such a condition, whereupon the mastoid is opened and nothing found, and *vice versa*, we often see cases in which the X-ray plate allows us to assume that the bone is in a comparatively normal condition, and when opened we find to our astonishment a most extensive destructive process. One cannot decry the usefulness of X-ray examinations of the mastoid bone, but one must not lose sight of the fact that the clinical symptoms and our clinical experience are the main factors in establishing the diagnosis of mastoid disease, so that one should never rely on the X-ray findings alone. The radiograph taken in conjunction with our clinical symptoms does, in many cases, aid us in making the diagnosis of mastoid disease, and is in such instances of great value.

From a large number of observations it has been found that after the action of great violence to the cranial bones a high degree of deafness, subjective noises, dizziness, and a staggering gait may also be produced without a fissure of the bone. The anatomical changes in the labyrinth in such cases are not known; still, it is probable that in many instances hæmorrhages (ecchymoses) take place into the labyrinth, while in others a paralysis and irritation of the terminal filaments of the acoustic nerve are brought about by the concussion alone. Such concussions of the auditory nerve apparatus terminate either in a permanent disturbance of hearing, with or without subjective noises, or in recovery.

In a case reported by Schubert (*A. f. O.*, vol. xxx.) of concussion of the labyrinth from a fall on the head, recovery ensued at the end of thirty days Ostmann (*Deutsche milit. arzll. Zeitschr.*, 1896) also saw complete recovery follow strychnine injections in a case of concussion of the labyrinth accompanied by a high degree of deafness, after a fall against the edge of a bed. Delie (*Rev. mens. de laryng.*, 1886) reports a case in which unconsciousness, followed by loss of hearing and speech, developed from a blow on the occiput, and in which recovery took place after the affection had lasted nearly one year. Schwartze (*Handbuch*, vol. ii.) saw a temporary disturbance of hearing follow the operative removal of exostoses from the external meatus (concussion of the head). According to Gradenigo (*Haug's Vorträge*, 1896), even slight concussions of the head are sufficient to produce a hystero-traumatic disturbance

of hearing. Concussions of the head have a deleterious effect in those cases in which an aural affection associated with disturbance of hearing has already existed, as even very slight shocks suffice to bring about an aggravation of the latter.

Blau (*A. f. O.*, vol. xv.) reports the case of a man, twenty-seven years of age, who had been deaf in his right ear since childhood, owing to an aural affection acquired during an attack of measles, and who became totally deaf in his left ear within two hours after a violent blow on the top of the head, with symptoms of roaring noises in the head, ringing of bells, staggering gait, and vomiting. After the administration of potassium iodide and purgatives, the symptoms disappeared, and the patient regained his former power of hearing within three weeks. Barnick (*Archiv für Ohrenheilk.*, vol. xliii.) reports four cases of fracture at the base of the skull, in which the labyrinthine capsule was not affected. In these cases hæmorrhages were found in the perilymphatic spaces, in the acoustic nerve and in its branches. Lange (*Archiv f. Ohrenheilk.*, vol. liii.) reports a case of fracture of the base of the skull, in which the auditory nerve in the internal meatus was torn without an injury to the labyrinthine capsule.*

We must add here the permanent paralyses of the acoustic nerve, which have been described as a part of a general traumatic neurosis following railroad accidents (railway spine) (Buss, Baginsky). In five cases of this nature Baginsky found a diminished perception for the higher tones of the tuning-fork, and a positive Rinne, with an intact sound-conducting apparatus.

Concussions of the terminal filaments of the acoustic nerve are brought about by the sudden condensation of the air in the external meatus, or by the action of intense noises in the immediate neighbourhood of the ear; the former are most frequently caused by a blow on the ear (box on the ear), while the latter are produced by violent detonations (cannon, pistol, or gun shots, locomotive whistles, etc.). In cases in which the condensation of the air in the meatus is due to a box on the ear, the concussion of the labyrinth is much more intense in those instances in which the membrana tympani remains intact, because the entire force of the blow is transmitted by the foot-plate of the stapes to the labyrinth; in those cases, however, in which the membrane is ruptured, the greater portion of the active force is expended in causing the rupture. The same applies to concussions of the labyrinth which are caused by detonations, and which are not complicated with a rupture of the membrana tympani.

Wittmaack reported interesting anatomical changes in the labyrinth which were brought about by the action of violent sounds. From his investigations the following may be gathered: The action of a severe sound (bell signals) alone, if conducted through the air, and not in the immediate vicinity of the ear, and even if continued for a long time, does not cause any injury to the organ of hearing. On the other hand, marked disturbances are brought about when the sound is conducted through the cranial bones. Extensive changes in the auditory nerve, in its ganglion cells, and in the cells of Corti's organ, are then found. Sudden loud noises (tones of a whistle), acting directly upon the ear, also cause marked injury to the cells of Corti's organ and to the nerve itself.

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* Injuries of the organ of hearing have been thoroughly reviewed by Passow (*Monographie*, Wiesbaden, 1905).

The symptoms of concussion of the labyrinth vary according to the intensity of the condensation of air in the external canal, and to the violence of the sound. Detonations in the immediate vicinity of the ear and in closed spaces, as, for instance, in covered shooting-galleries, prove especially injurious. Müller (*Zeitsch. für Ohrenheilk.*, vol. xxiv.) found in forty-eight artillery-men that only the organs of hearing which had already been in a diseased condition were injured by the detonations of the cannon.

In the slighter forms of labyrinthine concussion there is a moderate degree of deafness (a feeling of fulness in the ear), combined with a subjective buzz, which again disappears after several hours or days. In more severe concussions, on the other hand, a high degree of hardness of hearing comes on immediately, accompanied by marked subjective noises, a feeling of tightness in the head, and dizziness. As a rule, a diminution in the subjective symptoms takes place within a few days, but the hearing does not show a simultaneous improvement. There is almost always a marked hyperæsthesia acustica and the sensation of a shrill, metallic sound accompanying the perception for objective noises.

The perception through the cranial bones is either diminished or entirely lost, according to the degree of disturbance of hearing. The tone of a tuning-fork placed on the vertex is always lateralized towards the normal ear. The result of the hearing test taken in conjunction with the cause of the affection and the normal condition of the membrane allows one to make the diagnosis of concussion of the labyrinth, and especially so if, with deafness of a high degree, Rinne's test is positive, and the duration of perception for the tone of the tuning-fork through the cranial bones is shortened (Schwabach).

Disturbances of hearing in consequence of slight concussions of the labyrinth generally disappear within a few days or after several weeks. Sometimes a constant ringing or buzzing in the ear remains after the return of the normal hearing function. Severe concussions of the labyrinth due to detonations are usually followed by permanent and marked disturbances of hearing, so that single or a group of tones are no longer able to be perceived; a total loss of the hearing power is less frequently observed. The latter may, however, develop progressively from a deafness which was only slight at the beginning.*

The vestibular symptoms developing after injury to the labyrinth have been recently studied by Rhese, Friedrich, and Bárány. The last-mentioned author distinguishes (1) cases with complete destruction of the cochlear and

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* The treatment of concussions of the labyrinth is the same as that of paralysis of the acoustic nerve (*vide* the chapter on Neuroses of the Acoustic Apparatus, p 609).

vestibular apparatus following a fracture of the pyramid; (2) cases in which the irritability of the vestibular apparatus is preserved, and there are attacks of dizziness. In such cases the hearing may be more or less impaired; still, cases are met with in which the hearing power is normal or almost so (Rhese, *Zeitschr. f. Ohrenheilk.*, vol. l.). The attacks of dizziness appear especially when the head is rapidly rotated, when bending over, and during physical exertion; they may also come on without any external causes, and are always accompanied by a rotatory nystagmus towards the healthy side. The symptoms often last for years, and incapacitate the patient for work, especially if there is a co-existing traumatic neurosis. In young persons the symptoms of labyrinthine concussion disappear more rapidly.

It has already been mentioned (p. 174) that certain occupations (locksmiths, coopers, tinsmiths) in which continuous noises act upon the ear cause irritation and paralysis of the auditory nerve. Maljutin observed analogous disturbance of hearing in weavers. Gottstein and Kayser (*Bresl. ärztl. Zeitschr.*, 1881) and Thomas Barr very rarely found a normal condition of the hearing among lock- and blacksmiths, but very often found a marked diminution or entire absence of perception through the cranial bones. Habermann (*A. f. O.*, vols. xxx. and lxix, and *Deutscher Otologentag*, 1906) observed in coppersmiths) an atrophic condition of the auditory nerve and a partial disappearance of Corti's organ, which were limited mostly to the inner part of the base and the vestibular part of the cochlea. Brühl (*Zeitschr. f. Ohrenheilk.*, vol. lii.) found a similar condition in a coppersmith whom he had under observation during lifetime. In affections of the ear induced by the various trades, the results of the tuning-fork tests are characteristic of a primary diseased condition of the nerve; the perception through the cranial bones is greatly diminished, and Rinne's test positive; furthermore, there is a defect in the perception for the upper range of the scale, as well as for the tones of Galton's whistle. In half of the cases there are subjective noises. The disturbance of hearing is progressive, and often continues so, in spite of the fact that the patients avoid harmful noises and give up their occupations (Kahn, *Die Gewerbe und Berufskrankheiten des Ohres. Haug's Vorträge*, Jena, 1898).

The disturbances of hearing produced by the continuous use of the telephone must be reckoned among the anomalies of hearing brought about by the action of sound. Blake of Boston* was the first to call attention to this fact, and later Lannois,† Gellé,‡ and others. The first observations were made on individuals who had an affection of the ear, which was aggravated by the continuous use of the telephone.§ Owing to the increased employment of the telephone, a great many more aural affections are now observed in persons whose hearing was formerly normal. The most frequent symptoms are: hyperæsthesia acustica, subjective sensations of sound, a feeling of pressure and tightness in the head, and a progressive diminution in the acuteness of hearing. It is probable that the disturbances of hearing and nervous symptoms are induced by the intense cracking noise of the switchboard, which is often experienced in making the connection. In 26 per cent. of 371 telephone operators with normal hearing examined by the author, there was a retraction of the membrana tympani in the ear used in telephoning.

Signal Deafness in Railway Employés.—In the year 1857, Duchesne of Paris was the first to call attention to the frequent occurrence of deafness

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* *Influence of the Use of the Telephone upon the Hearing Power* (reprint from the *Archives of Otology*, vol. xvii., No. 3, 1888).

† *Annales des maladies de l'oreille*, 1889.

‡ *Soc. de Biologie*, 1889.

§ Cp. the recent observations of J. Tommasi, *Le lesioni professionalie traumatiche nell' orechio* (Atti del VII. Congresso della Società ital. di Laryng., d' Otol. e di Rinol., 1903), Napoli, 1904; Brühl, *Die Berufskrankheiten des Ohres* (*Zeitschr. f. ärztl. Fortbild.*, 1904).

and subjective noises in those employed on locomotives. Zwaardemaker (*Z. f. O.*, 1895) deserves the credit of having given us a complete review of aural affections in engine-drivers and stokers.

Moos, Bürkner, and others, believe that the aural affections in those employed on locomotives are due to the severe, continuous shaking, the persistent straining of the ears, the sharp currents of air, and the continuous irritation of the nasal and pharyngeal mucous membrane due to the inhalation of the injurious gases escaping from the locomotive. In the great majority of cases, otosclerosis, less often chronic labyrinthine affections, was found to be the cause of the hardness of hearing.* In selecting individuals for active railroad service, a normal hearing is an absolute necessity, because this occupation in itself brings about disturbances in hearing within a few years. If men are taken whose hearing is somewhat impaired, the affection soon shows a tendency to become aggravated.

Owing to the great danger which arises from the progressive deafness so often observed in engine-drivers and stokers, and to ensure the safety of the passengers, Moos, Schwabach, and Pollnow proposed that the companies should have the ears of their employés thoroughly examined by specialists at fixed intervals (under the term 'employés' Bürkner and Burckhardt-Merian include switchmen, brakesmen, signalmen, and guards). Moos (*Z. f. O.*, vol. xi.) later proposed that, by a careful examination of the ears of the employés of railroads, a limit of the acuteness of hearing should be established, which ensures the safety of the passengers. As many disturbances of hearing develop only during the time of service, such examinations would seem of value, in the author's opinion, only if repeated at regular fixed intervals. It is gratifying to notice that most of the companies have adopted this proposition.† In the periodical examinations, as well as in the examination of new applicants, the main attention must be paid to the hearing tests, irrespective of the conditions found by the otoscopic examination. In addition to this, we must see whether there are any disturbances in equilibrium and nystagmus, as these should debar the individual from railroad service.

A concussion of the labyrinth can be determined from a medico-legal standpoint only in those cases in which there is a fissure of the temporal bone which extends to the external meatus, and in which an injury of the labyrinth can be established from the discharge of cerebro-spinal fluid or from the complete deafness and the absence of perception through the cranial bones. Those concussions of the internal ear produced either by direct violence to the head or by detonations, in which the external meatus and membrana tympani present a normal appearance, are absolutely incapable of being judged from a medico-legal standpoint. The reasons for this are: (1) It cannot

* Cp. Guye, *Revue intern. de Rhinologie, Otologie*, etc., 1897; Kornél Liehtenberg, *M. f. O.*, 1891; Herzenstein, *Realencyklopädie*, vol. vii., pp. 162-169; Jankau, *Hygiene des Ohres*, München, 1895, p. 97; Gordon, *Hygiene des Ohres*, St. Petersburg, 1895; Pollnow, *Archiv f. Ohrenheilk.*, vol. xvi.; Wiehe, *Inaug.-Diss.*, Göttingen, 1893; Schwabach, *Zeitschr. f. Ohrenheilk.*, vol. x.; Braunstein, *Archiv f. Ohrenheilk.*, vol. lix.

† E. de Rossi deserves the credit of having collected the opinions of a large number of specialists on this subject, and also of having published the requirements of the various railroad companies (*Functional Examinations of the Ears of Railroad Employés*, Rome, 1898). Gordon, *Die Erkrankungen des Gehörorgans der Eisenbahnbediensteten;* Ferruccio Putelli, *Sull' esame dell' udito nei ferrovieri* (*Arch. ital. di otol.*, etc., vol. xviii.).

be positively proved that the paralysis of the auditory nerve is due to the presumed injury; and (2) even if the traumatic violence has been established, it cannot be positively determined whether the paralysis of the acoustic nerve has not existed prior to the time of the injury.

In considering disturbances of the vestibular apparatus from a medico-legal standpoint, we must consider mainly, according to Bárány, the spontaneous nystagmus, the nystagmus (dizziness) produced by movements of the head, and the rolling of the eyes in an opposite direction. If these disturbances are at hand, the presence of the dizziness can be established with certainty. If the injured person can prove that he did not suffer from dizziness prior to the injury, then it can be assumed that the dizziness elicited by the examination is due to the injury.

Cerebral Disturbances of Hearing.

Affections of the brain and its coverings are more often associated with disturbances of hearing than is generally supposed. It is only in recent years that interest has been aroused in this subject, yet the number of cases carefully examined clinically, in which the disturbances of hearing have been observed and followed from the very beginning, is yet too small to form the basis of a pathology of cerebral disturbances of hearing. It must be stated here that the clinical observations do not agree in many respects with the results of experiments on animals, as reported by many well-known investigators.

Cerebral disturbances of hearing are produced either by affections of the acoustic centre, by extension of the pathological process from the brain and its coverings to the nuclei, roots, or origin of the auditory nerve, or, finally, by transmission of the pathological process from the cranial cavity to the labyrinth.

Disturbances of hearing are occasioned by a number of diseases of the brain, of which the following are the most important: Hæmorrhages, emboli, softening of the brain due to embolism, encephalitis, chronic sclerosis, acute and chronic hydrocephalus, gummatous and tubercular lesions, and new growths in the brain itself and at the base of the skull.

According to clinical experience based on *post-mortem* examinations, the degree of disturbance of hearing depends less on the extent than on the seat of the disease. Diffuse pathological processes in the brain (abscesses, hæmorrhages, new growths) not infrequently run their course without any disturbances of hearing; while, on the other hand, the latter are well developed in pathological changes involving only a small area if these affect the acoustic, cortical centres in the temporal lobes, their communications with the acoustic nuclei, the acoustic nuclei themselves, and the roots of the acoustic nerves.

Disturbances of hearing in consequence of apoplexy are, on

the whole, rare. Subjective noises are often observed as a premonitory symptom of an apoplectic attack. According to Moos, severe disturbances of hearing are produced most frequently by hæmorrhages into the pons and cerebellum. Crossed cortical deafness, which is observed in affections of the cerebral hemispheres, allows us to assume that the first convolution of the temporal lobe of each side is in relation with the ear of the opposite side. The fact which has been established clinically, however, that in unilateral affections the crossed deafness sometimes disappears again, shows that each acoustic nerve is in communication with both temporal lobes.

Kaufmann (*Berl. klin. Wochenschr.*, 1886) observed a case of crossed cerebral deafness of the left ear in which the right cerebral hemisphere had become softened owing to an obliteration of the arteria fossæ Sylvii. Wernicke and Friedländer report a case of bilateral, total deafness associated with temporary aphasia, in consequence of a symmetrical, gummatous deposit in the region of the corona radiata of both temporal lobes. Further communications in reference to complete deafness, as a result of bilateral affections of the temporal lobes, have been published by Pick, Anton, Broadbent, Shaw, Banks, Mills, and others.

Acute hydrocephalus is more often the cause of marked disturbances of hearing. The inflammatory changes on the floor of the fourth ventricle which accompany this affection, lead to softening and atrophy of the auditory nuclei. That the anatomical changes which take place in these nuclei during the course of acute hydrocephalus may recede is shown by the cases in which total deafness (also blindness) arising during the course of the disease again disappears entirely after the process has subsided. Acute and chronic internal hydrocephalus often leave permanent bilateral deafness and deaf-mutism. Meyer (*Virch. Arch.*, vol. xiv.) found, in an individual whose hearing had been normal and who had become deaf, nodular and irregular thickenings of the ependyma of the fourth ventricle, with a disappearance of the striæ acusticæ and destruction of origins of the acoustic nerve, as the result of a fatal ependymitis. In the chronic forms of hydrocephalus the deafness is caused by the basilar meningitis which often accompanies it, and is associated with a consecutive neuritis ascendens, and by pressure atrophy of the acoustic root and nucleus.

The author had occasion to examine a young man who, with symptoms of hydrocephalus, became paralyzed in all his extremities during the course of a number of years; the patient also became totally blind and deaf, and died from general marasmus. The autopsy revealed a growth (osteosarcoma) arising from the sella turcica, hydrocephalus, dilatation of the ventricles, atrophy of the cerebral substance, marked thinning of the cranial bones, the origin of the optic nerve flattened, but no changes in the bulbus oculi itself, and the internal auditory canal widened to three times its original size. The acoustic, together with the facial, nerve was represented by a thin, thread-like nerve bundle; the membrana tympani was thickened and adherent to

the inner tympanic wall by means of firm, connective-tissue adhesions; the ossicles were moved with difficulty, and abundant accumulations of amorphous pigment were present in the cochlea.

Word-Deafness.—In opposition to the deafness for every kind of sound which is occasioned by a lesion in the cortical centre of hearing, pathological conditions are known in which the power of hearing is retained, but in which the comprehension for the different forms of sound—as speech and tones—has become impaired. In a number of cases reported by Wernicke, Kahler and Pick, Broadbent, and others, in which the *post-mortem* examination revealed marked changes in the left temporal lobe (seat of encephalitis, embolic softening, compression of the temporal lobe by an exudate owing to hæmorrhagic pachymeningitis, tubercle of the brain), it was observed that during the life of the patients they were not able to understand speech, although a thorough functional examination of their organs of hearing demonstrated that they could perceive sounds. This fact led Wernicke to believe that the sensory centre for hearing lies in the cortex of the left temporal lobe, where the irritations transmitted from the auditory nerve are formed into images of sound or into acoustic word-pictures. After the loss of this centre—in cases in which the auditory apparatus and acoustic nerve are otherwise normal — sound may still be perceived, but words cannot be comprehended; this condition is termed ' sensory aphasia ' by Wernicke (1874), and ' word-deafness ' by Kussmaul.* According to Wernicke. sensory aphasia is localized in the posterior third of the left gyrus of the superior temporal lobe; still, some, supported by the conditions found at *post-mortem* examinations, think that the superior portion of the middle convolutions of the temporal lobe should also be added to the so-called acoustic centre for speech. Wernicke's opinion has been mainly supported by the researches of Kahler and Pick, Kussmaul, Huguenin, Fritsch, N. Weiss, Drozda, and others (in all about eighty cases). The clinical observations, however, that the comprehension for sound may be regained after destruction of the temporal lobe does not point to a sharply-defined, acoustic, cortical centre, but rather suggests that there must be other groups of ganglion cells in the cortex of the brain which assist in the power of hearing, and through which the patients again learn to hear after the loss of the true hearing centre.†

Disturbances of hearing due to some local lesion in the brain

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* It is interesting to read in Kussmaul's *Störungen der Sprache* (Leipzig, 1877) an account of Professor Dr. Lordat, who, after his recovery from a long-standing aphasia, stated that during the time of the affection words were unintelligible to him, and that he was not able to understand anything printed or written.

† The observation of Westphal, which has been confirmed, is worthy of note; he states that in cases in which Wernicke's centre was destroyed, and in which no word-deafness resulted, the individuals were found to be left-handed.

manifest themselves in a great variety of forms. Some patients hear the words spoken to them, but are unable to repeat them. Others have completely lost the memory for certain things (amnestic aphasia), or they do not call objects by their proper names. Others, again, designate everything set before them by the same term, as, for instance, they may continually use the word ' key ' (monophasia). In like manner it is found that they are unable to write the words they hear, or the names of objects set before them (amnestic agraphia).

A case observed and examined *post-mortem* by Finkenbach shows that word-deafness may also arise without changes in the temporal lobe. The claustrum, which is in intimate communication with the cortex of the temporal lobe, the lenticular nucleus, and the superior and middle convolutions of the frontal lobe, were found to have undergone a pathological softening. In a case of Colley's (in Castex, *Bull. de laryngol., otol.*, etc., 1900) of left-sided deafness, hemianopsia, and hemianæsthesia, the *post-mortem* examination showed softening of the internal capsule and of the lenticular nucleus. The author observed a case of aphasia in which the cerebral hemispheres were intact, but in which a diffuse abscess occupied both halves of the cerebellum. Urbantschitsch saw temporary aphasia accompanying an extradural abscess of the posterior cranial fossa. In this case the aphasia was no doubt due to an increased endocranial pressure (indirect action).

The total deafness which is associated with aphasia may recede entirely, while the aphasia may continue, as was observed in a case reported by Holländer.

Nothnagel considers it probable that the conditions found in these cases are analogous to those observed in the eye. The disturbances of hearing must therefore be distinguished: First, simple cortical deafness; second, mental deafness in which the patient cannot interpret any impressions of sound—that is, he is not only unable to comprehend words spoken to him, but also the ripple of a brook, the barking of dogs, the sound of a horse's hoofs, etc.; third, true word-deafness in which the patient possesses the ability to understand all sensations of hearing, but cannot form sound-images.

Rumpf (*Die syphilitische Erkrankung des Centralnervensystems*, Wiesbaden, 1887) emphasizes the fact that word-deafness is not infrequently the result of a syphilitic affection of the brain; he also shows that it may be produced by gummatous affections of the cortex, as well as by the formation of syphilomata in the corona radiata, and that it is, as a rule, associated with hemiplegia. Transitory word-deafness of short duration may also arise, according to Kahler and Pick, from embolism of the arteria fossæ Sylvii, if the embolus produces considerable circulatory disturbances in the cortex of the temporal lobe.

Deafness for musical tones (called ' amusia ' by Knoblauch) has been less often observed than word-deafness. It becomes apparent in different forms, as absolute deafness for tones, as false interpretations of the same, as musical amnesia, agraphia, alexia, and paralexia. Of all these, auditory tone-deafness, which corresponds to Wernicke-Kussmaul's word-deafness, is the most common form. It consists, namely, in that persons in whom it has been found that the hearing for tones and noises is retained, and who possess a good perception for rhythm and pitch, have entirely lost the interpretation of melodies

(Alt).* From the few cases examined *post-mortem* by Déjerine, Edgreen, Bernard, and others, it was found that tone-deafness is produced by a lesion of the first and second convolutions of the left temporal lobe. According to Monakow,† tone-deafness is brought about by a bilateral affection of the first convolution of the temporal lobes. It may be combined with word-deafness; it may be present, however, without the latter, or it may be far less pronounced. In the majority of cases, the musical aphasia was associated with disturbances of hearing, which were regarded as the sequelæ of a simultaneous diseased condition of the brain and labyrinth (syphilis, meningitis).

Disturbances of Hearing due to Brain Tumours.—Of all the cerebral diseases, tumours are most frequently combined with disturbances of hearing. Such disorders of the ear may be produced by pressure, pulling, separation, or disorganization of the central course or origin of the auditory nerve.‡ It has been especially noticed that new growths in the posterior cranial fossa, arising from the cerebellum, pons, dura and pia mater, as well as those growing from the brain itself to the base of the skull, give rise to pressure paralysis of the auditory nerve. The sarcoma, myxoma, glioma, carcinoma, and gumma have been found to be most frequently—the psammoma and cholesteatoma less often—the cause of cerebral disturbances of hearing.

According to Moos, the increased intracranial pressure produced by a tumour can bring about disturbances of hearing by indirect action upon the nerve root. Chronic basilar meningitis, which nearly always exists with brain tumours, and the ascending neuritis acustica produced thereby, are also often the cause of disturbances of hearing.

The statistics of Calmeil (*Dict. de méd.*, vol. xi.) show that there are disturbances of hearing in one-ninth of all cases of brain tumours; Lebert (*Virch. Arch.*, vol. iii.), in about 20 per cent.; and Ladame, 17 times in 175 cases; these figures, however, hardly represent the true proportion, as unilateral deafness is very often overlooked by clinicians, and, furthermore, because in the majority of cases it is not ascertained whether the disturbance of hearing is not due to an altered condition of the sound-conducting apparatus existing at the same time. It is worthy of note, however, from Ladame's compilation, that tumours of the pons are most often accompanied by disturbances of hearing, while growths in the parietal and occipital lobes and in the fourth ventricle do not cause any deafness.

From a large number of observations it has been noticed that tumours in the region of the corpora quadrigemina and tegmen, produce disturbances of hearing in the ear of the opposite side (Weinland, Ilberg, Nothnagel, Hoppe, and others). Siebenmann (*Deutsche Ot. Ges.*, 1896), who examined 59 cases of tumour in the region of the corpora quadrigemina and of the tegmen, found disturbances of hearing 11 times; these were always bilateral and combined with paralysis of other nerves. Weinland (*Arch. f. Psych.*, vol. xxvi.) has

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* *Über Melodientaubheit und musikalisches Falschören*, Leipzig and Vienna, 1906, Franz Deuticke.

† C. v. Monakow, 'Gehirnpathologie,' in *Nothnagel's spec. Pathologie u. Therapie*, vol. ix., Part I., Wien, 1897.

‡ Gomperz, *Arch. f. Ohrenheilk.*, vol. xxx

reported in his collection of 19 cases of tumour of the corpora quadrigemina, disturbances of hearing 11 times, of which 5 were bilateral and 4 crossed. Monakow (*loc. cit.*) is of the opinion that the disturbance in hearing in these cases was due to an indirect action on the acoustic nerve and on the inferior lemniscus. A few observations have been recorded by Rosenthal and Rhomberg in reference to collateral disturbances of hearing in isolated lesions of the pons. The disturbances of hearing which arose in the ear of the same side or in the opposite one in cases of isolated affections of the cerebellum, were attributed to pressure upon the tegmen, upon the inferior corpora quadrigemina of the medulla oblongata, or upon the auditory nerve. In these cases it was noticed that the loss of hearing appeared early. Fera (*Arch. ital. de otolog.*, vol. ix), Druault (*Ann. de mal. de l'oreille*, etc., 1898), Gray (Intern. Otol. Congress, London, 1899), and Silva (*Boll. della Soc. med. chir. di Torino,* 1897), have reported interesting observations in reference to tumours (sarcoma and glioma) at the base of the skull, which were associated with disturbances of hearing and paralysis of the cranial nerves (paralysis of the recurrent laryngeal nerve, hemiplegia, blindness). A. A. Grey (*Revue hebdomad.*, 1899, No. 39, ref. *Arch. f. Ohrenheilk.*, vol. xlix., p. 274) reports a case of gliosarcoma of the medulla oblongata which was confined to the left side, and which produced left-sided deafness, dizziness, paralysis of the left side of the body, palate, and the left vocal cord, and also a right-sided hyperæsthesia.

The symptoms of lesions of the acoustic nerve and of its central course produced by tumours of the brain are: Subjective noises, dizziness, nystagmus, and hardness of hearing of a varying degree up to total deafness, in consequence of which the subjective noises generally disappear. In the majority of cases the disturbance of hearing is unilateral; still, cases are not infrequently met with in which bilateral deafness develops from pressure upon the opposite side of the brain, or from extension of the growth to the other side. According to Bárány, in cases of tumour at the base of the brain in the posterior cranial fossa, an impaired irritability of the vestibular apparatus, associated with severe dizziness (by injection of cold water into the external meatus) and a nystagmus to the diseased side, arise early in the disease—symptoms which considerably aid the diagnosis of tumour at the base of the brain if, at the same time, the membrana tympani has a normal appearance. All tumours of the posterior cranial fossa show the early development of choked disc.

If the tumours at the base of the brain continue to grow, they produce pressure paralyses at the base of the brain, which especially involve the facial, trigeminus, and abducens nerves. Sometimes paralyses of the extremities also arise, which are usually on the opposite side to the tumour. Pressure on the pons produces paralysis of the muscles of the eyes towards the diseased side, while pressure on the medulla oblongata brings about anarthria, disturbances in swallowing, etc. A slow pulse is frequently met with. Small tumours at the base of the brain often bring about severer disturbances than large tumours in the substance of the cerebellum itself. In such cases there are often, with the exception of the headache, choked disc, dizziness

with nystagmus, and a rigidity of the head, no objective disturbances of any kind. It is only in the later stage that a unilateral ataxia of the extremities, a cerebellar gait, and pressure symptoms arising from the pons and medulla oblongata are observed.*

Two cases must be mentioned here which were observed by the author. The first was that of a man, twenty-four years of age, who suffered from headaches since childhood, and in whom, after a gradual diminution in the hearing in the right ear, there developed vomiting and weakness in the field of vision, which were soon followed by a right-sided facial paralysis, dizziness, and tinnitus; in the last stage of the affection there were unconsciousness and stupor, disturbances in mobility of the upper extremities, gradual blindness, and exophthalmos. Hearing for speech $= o$. All tuning-forks placed on the vortex were perceived only in the left ear. Death ensued with symptoms of a general paralysis. The autopsy showed that the ventricles were distended to double their size, and that the right cerebellar hemisphere was occupied by a cyst the size of a goose's egg, the contents of which consisted of an aqueous serum. In a second case, with a similar clinical course, and in which sudden total right-sided deafness developed two months before death, there was found in the enlarged right half of the cerebellum, a cystic tumour the size of a man's fist, which was filled with a brown fluid, and which proved to be a sarcoma.

Burckhardt-Merian (A. f. O., vol. xiii.) found a fibrosarcoma of the dura mater in a man sixty-six years old, who had become deaf owing to an otorrhœa acquired during an attack of typhoid fever. This growth originated above the place of union of the inferior petrosal sinus and the sinus of the internal jugular vein, and divided here into two branches; the one entered the vestibule as a round band through the enlarged aquæductus cochleæ, while the other ran under the floor of the internal auditory canal to the adventitia of the carotid, partially encircling the necrosed cochlea. Field reports a case of sarcoma the size of an orange on the posterior surface of the petrous bone and in the internal auditory canal, which arose from the dura mater and destroyed the acoustic nerve. Moos (A. f. A. u. O., vol. iv.) describes the case of a woman, forty-seven years of age, who had a sudden anæsthesia of the left side of the face, weakness of vision in the left eye, lachrymation, ptosis, headache, vertigo, and deafness, and who died one year later with symptoms of asphyxia. The examination revealed on the outer side of the left internal auditory canal a round, spindle-celled sarcoma the size of a walnut, into which the auditory nerve could be traced only for a short distance. The growth was connected with the crura cerebelli, and pushed the medulla oblongata over towards the right side. A second, uneven tumour the size of a pea was found in the internal auditory canal, which was considerably dilated. The cranial nerves, the cervical and dorsal portions of the spinal cord, and the terminal filaments of the acoustic nerve in the labyrinth had all undergone degeneration. Vermyne found as the cause of blindness, which was followed seven years later by total deafness, a myxofibroma on the base of the skull which had extended into the labyrinth. Virchow (Geschwülste, vol. ii., cited by Schwartze) describes a psammoma of the dura mater the size of a mulberry, which, springing from the internal auditory canal, and forcing its way through, produced paralysis of the acoustic and facial nerves through compression. Schwartze (A. f. O., vol. v.) saw a tubercular growth which compressed the auditory and facial nerves in a child two years old. Stevens (Z. f. O., vol. viii.) describes the case of a girl seventeen years of age in whom convergent strabismus, deafness in the left and hardness of hearing in the right ear, imbecility, awkward movements, slow speech, uncertain gait, weakness, a feeling of heaviness in the right

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* The monographs of Oppenheim and Bruns deserve a careful study.

extremities, and a left-sided frontal and occipital headache had existed for a long time. The autopsy revealed a globular sarcoma of the cerebellum with nodular elevations, from which an offshoot forced its way into the internal auditory canal. The auditory nerve had become involved in the tumour. so that the communication between the peripheral fibres and their central origin was broken off. Krepuska (*Ungar. Arch. f. Med.*, 1894) reports the case of a gliofibroma of the acoustic nerve. Donault (*Annal. d. mal. de l'oreille*, 1898) saw a sarcoma of the acoustic and facial nerves, which had grown into the widened internal auditory meatus.

The author is indebted to Dr. van Millingen, of Constantinople, for an interesting specimen in his collection of an intracranial tumour (neurofibroma) which had penetrated into the internal auditory meatus. The patient was a woman who had been totally deaf in both ears for ten years, and who had occasional attacks of delirium in her childhood. No anomalies were noticeable
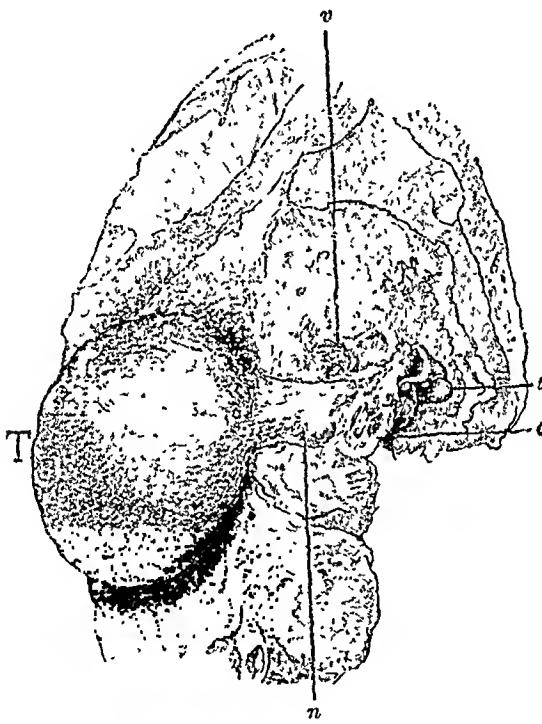
FIG. 292.

on her head, except the striking length of her auricles (10 cm.). Three months prior to her death optic neuritis of both eyes developed, which resulted in complete blindness, and which was soon followed by a left-sided facial paralysis and dementia. Death took place in a state of coma and convulsions.

The autopsy showed (Fig. 292) a somewhat uneven, globular tumour (T), nearly the size of a walnut, which covered most of the posterior surface of the petrous portion of the temporal bone. It surrounded the acoustic and facial nerves in the form of a band, which grew smaller as it proceeded outwards, completely filling the lumen of the internal auditory meatus, and reaching as far as its fundus. The acoustic and facial nerves were also involved in the tumour at this place, and the central portion of the nerve could no longer be distinguished. No changes were noticeable in the tympanic cavity, in the vestibule (v), or in the cochlea (c).

We must also mention here the neurofibromatosis multiplex described by

Recklinghausen, in which one frequently observes the symptoms of tumour of the acoustic nerve.*

A round-celled sarcoma (Ziegler) having a green colour has been described under the name of chloroma (Körner), which, taking its origin from the dura mater and the walls of the sinus,† surrounded the acoustic and facial nerves, and grew into the internal auditory canal (Lubarsch, *Zeitsch. f. Ohrenheilk.*, vol. xxxii.). Chloroma, which occurs especially in children and young persons, is always manifold and bilateral. Compression paralyses of the acoustic nerve will be discussed under Cerebral Disturbances of Hearing.

Diagnosis.—The diagnosis of disturbances of hearing due to brain tumours can rarely be made in that stage in which, irrespective of the deafness, there are no apparent symptoms of irritation or paralysis in the areas supplied by other cranial nerves. At that period of the process the differential diagnosis between a peripheral and central disturbance of hearing is made with difficulty, because deafness, tinnitus, and attacks of dizziness may also be occasioned by an affection of the labyrinth associated with a negative condition of the middle ear, as well as by a central lesion. In both cases the tone of the tuning-fork placed on the vertex will be lateralized towards the normal or, as the case may be, the better-hearing ear. The early appearance of facial paresis and the retained perception for the watch and acoumeter through the cranial bones are important guides for a differential diagnosis. According to Moos, the perception for the high tones of the tuning-fork is reduced; Siebenmann (*loc. cit.*) is supposed to have observed no decided changes in the perception for high or low tones in cases of tumour involving the corpora quadrigemina. According to Gradenigo (*A. f. O.*, vol. xxvii.), the increased electrical irritation of the acoustic nerve with an intact organ of hearing may be regarded as an important early symptom of brain tumour.

The diagnosis is also rendered difficult in those cases in which there are no other symptoms of cerebral compression, and in which there is a middle-ear affection existing at the same time, which, as has been seen, may also run its course with dizziness and disturbances of equilibrium.

The following case observed by the author is a striking example of this kind: The patient was a girl, twenty-six years of age, who had suffered for a number of years from a left-sided, middle-ear suppuration which was associated with subjective noises and dizziness. After treatment for several months the discharge from her ear ceased, and she was dismissed, having, however, a perforation in Shrapnell's membrane, and an adherent cicatrix behind the handle of the malleus. In spite of the improvement in the hearing, tinnitus and dizziness remained. When the patient presented herself again at the

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* Cp. Henneberg and Koch, *Über zentrale Neurofibromatose und die Geschwülste des Kleinhirnbrückenwinkels (Akustikusneurome)*, *Arch. f. Psych. und Nervenk.*, 1903, vol. xxxvi.; Hammerschlag, *Monat. f. Ohrenheilk.*, 1906.

† Ayres, *American Journal of Ophthalmology* 1907; Körner, *Zeitschr. f. Ohrenheilk.*, vol. xxx.

clinic some months later on account of a feeling of tightness in the head, increased dizziness, and disturbance of equilibrium, suspicion was aroused that a central lesion might be developing.

The diagnosis of brain tumour could be made with certainty only when the patient came to the hospital some months later with bilateral weakness of vision, hardness of hearing of a high degree, and paresis of the extremities. During her stay in the hospital she gradually became totally blind and deaf in the course of several months; the paresis of the extremities rapidly increased, and death followed with symptoms of general paralysis.

Autopsy.—A somewhat irregular oval tumour, the size of a goose's egg, which consisted of fatty degenerated mucous tissue, and which took its origin from the meninges, was found on the right half of the pons and in the right crus cerebelli ad pontem, situated in the triangle formed by the places of origin of the trigeminus, facial, acoustic, and abducens nerves. On cross-section the growth presented a white, transparent, vascular appearance, and enclosed several cysts the size of peas, which were filled with a clear serum. The right half of the pons Varolii, the right crus of the cerebellum, and the right crus of the cerebrum were all flattened owing to the pressure of the tumour. In like manner the right pyramid and olivary body of the medulla oblongata, and the anterior third of the inferior surface of the right hemisphere of the cerebellum, were compressed. The abducens nerve was displaced medially, and the trigeminus, facial, and acoustic nerves ran along the outer surface of the tumour. The latter nerves were greatly compressed, and their fibres were markedly separated from each other.

The disturbances of hearing may be attributed with greater certainty to a tumour of the brain if they are combined with signs of paralyses of other cranial nerves. Thus, the tumour may bring about crossed paralyses with increased reflexes by compression of the pyramids of the cerebellum. Paræsthesia in the extremities develops at the same time. Furthermore, paralyses of the ocular muscles (abducens, motor oculi) and disturbances in smell and taste have been observed. When the symptoms of brain tumour are not very pronounced, it must be specially noticed whether a slight facial paresis and anæsthesia of the skin on the affected side of the head are present, as these may easily be overlooked if the examination is carried out perfunctorily.

Disturbances of Hearing in Locomotor Ataxia.

The disturbances of hearing in locomotor ataxia, to which Duchenne (1859) had already called attention, are, according to the cases thus far anatomically investigated, due to atrophy of the acoustic nerve. Erb (*Ziemssen's Hand-buch*, p. 142) found atrophy, while Wernicke and Althaus observed a gray degeneration of the acoustic nerve; Habermann found marked atrophy of the nerve and ganglion cells in the cochlea, connective-tissue degeneration of the cochlear and vestibular nerves, in addition to an excessive accumulation of corpora amylacea, and a central extension of atrophy of the acoustic nerve up to its nuclei. Strümpell (*Arch. f. Psychiatrie*, 1881) saw degeneration of both acoustic nerves; Oppenheim and Siemerling (*ibid.*, 1887) reported degeneration of the acoustic roots; and Haug (*Die Krankheiten des Ohres*, etc.. 1893) degeneration of the central labyrinthine portion of the vestibular and cochlear nerves. Friedrich (*Verhandl. d. deutsch. otol. Gesellsch.*, 1897) believes that the apoplectiform tabetic deafness is due to a diseased condition of the

nuclei of the acoustic nerves in the medulla oblongata. P. Bonnier* thinks the disturbances of hearing in tabes are caused by pathological changes in the nuclei of the acoustic nerve and in its peripheral terminal filaments in the labyrinth. Brühl found in a deaf tabetic patient, almost a complete absorption of the ganglion cells in the spiral ganglion of the cochlea, and atrophy of the auditory nerve up to its nuclei in the medulla oblongata (*Zeitsch. f. Ohrenheilk.*, vol. lii.). The changes in the auditory nerves of tabetic individuals are supposed to be due to a metaluetic process.

The clinical investigations of 53 tabetic individuals examined by Morpurgo and Marina (*A. f. O.*, vol. xxx.) showed that aural affections may arise in any stage of locomotor ataxia. Of the 53 patients, only 10 had normal hearing; in 35, who were hard of hearing, Rinne's test was positive; in 35 cases the tone of the tuning-fork placed on the vertex was lateralized only 11 times towards the more affected ear. Marie and Walton (quoted by Bonnier) have observed disturbances of hearing 17 times in 24 tabetic patients. Friedrich (*loc. cit.*), on the other hand, found disturbances of hearing only twice in 27 cases; Treitel twice in 20 cases; and Voigt only in 2 per cent.

According to the observations of the author, deafness in tabes dorsalis generally develops progressively, seldom rapidly, and is accompanied by a marked unbearable tinnitus. Occasionally it appears as the initial symptom of tabes, but usually develops only in the advanced stage of the affection. The aural disease is, as a rule, bilateral. Dizziness is a common symptom. Bonnier is of the opinion that this phenomenon is produced by a tabetic condition of the nucleus of the vestibular nerve. Collet,† who attributes the aural affection in persons having tabes to trophic disturbances, just as in other nerves, observed a neuralgia of the trigeminus of varying degree in two-fifths of the cases.

Not every disturbance of hearing arising in the course of locomotor ataxia must be looked upon as due to this affection. One not infrequently finds, however, in persons having tabes dorsalis obvious changes in the middle ear, or symptoms of an otosclerosis with a striking negative Rinne, which may be considered the cause of the hardness of hearing. Cassierer and Schiff (*Arbeit. aus d. Instit. f. Anat. u. Physiol. d. Central-nervensyst. d. Wien. Univers.*, 1896) found the roots of the auditory nerve completely normal in two deaf tabetic patients, in whom the author observed extensive changes in the middle ear.

Disturbances of hearing have also been observed in progressive paralysis (Magnan). In the beginning of this affection, there is a marked hypersensitiveness for high tones (Haug). In the stage of advanced dementia, the hearing test is associated with insurmountable difficulties. According to the histological examinations of Otto Mayer (*Archiv f. Ohrenheilk.*, vol. lxxii.), it is observed that marked disturbances of hearing develop in the terminal stage of the ascending paralyses of tabes. Mayer found degenerative changes in the ganglion of the root, and a breaking up of the auditory nerve, which could be traced into the medulla, and were

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* *Le tabes labyrinthique* (*Nouvelle iconographie de la Saltpetrière* (separate copy).

† *Les troubles auditifs du tabes*, Lyon, 1894.

of a tabetic nature. In addition to this, he could find in other cases, a marantic degenerative neuritis, an interstitial inflammatory process in the auditory nerves, and degenerative changes in bloodvessels of the labyrinth.

Malformations of the Organ of Hearing.

Malformations of the organ of hearing are frequently the anatomical basis of deafness and deaf-mutism. They either occur with malformations of other organs, or are limited to the ear alone. Of the latter, the bilateral anomalies of formation are of special significance. The malformation is often limited to only certain portions of the ear, or it involves the entire organ of hearing. It is found, therefore, that the internal ear is in a normal condition, with a marked malformation of the external and middle ear, and, *vice versa*, that the latter is perfectly formed, with an arrest of development in the labyrinth.

Structural anomalies of the auricle are rather frequent, and appear either as an excessive or defective formation. Among the former may be classed: congenital excessive enlargement of the auricle; the occurrence of two (Knapp) or more auricles (Cassebohm Langer) on one side (polyotia); and the so-called auricular appendages (Virchow), which project as isolated portions of cartilage in front of the tragus, or below the auricle in the form of round or elongated prominences (Fig. 293). These excessive formations are usually confined to the auricle, while defects in its development are, as a rule, also combined with defects of the external meatus and middle ear, less often with those of the labyrinth (J. P. Cassels). Anomalies in the position of the auricle are also found, so that it may be situated upon the cheek, less often upon the neck.*

Defective formation of the auricle is characterized either by its total absence, by a stunting and shrivelling of the cartilage, or by malformation of its different portions. The changes of form thus produced are very numerous. The auricle sometimes appears as a rudimentary growth of skin or cartilaginous appendage, and sometimes as a hook-shaped fold which is either spirally curved or rolled together in the form of a cone. It may also appear as a cauliflower excrescence, not infrequently as a so-called cat's ear, but most frequently as a long cartilaginous swelling, as shown in the accompanying cut (Fig. 294). Congenital fissure of the lobule is rather common (coloboma auriculæ).

According to Rohrer, the greater number of anomalies of formation of the auricle are undoubtedly due to the development of this organ *in utero*. The most important embryological factors in producing such malformations are: faulty closure of the two upper branchial clefts, arrest of the unrolling process of the auricle during its development, division or splitting of the original formation, etc. The complete absence or rudimentary development of the auricle which is often associated with a co-existing faulty development of the corresponding side of the face is especially noticeable.

Of the malformations of the external meatus one must mention the excessive development in size, such as marked dilatation, and a double canal, which are

* Cp. Apert, *Arch. intern. d'Otologie*, 1903; Sassjedatelew, *Med. Obosr.*, Moscow, 1903 (Russian); Neuenborn, *Archiv f. Ohrenheilk.*, vol. lxiii.; Novak, *Prager med. Wochenschr.*, vol. xxx.

rather uncommon.   In the latter one finds, as in the cases reported by Velpeau and Macauln (*The Specialist*, London, 1881), a second cul-de-sac behind the true auditory meatus, or there may be two separate canals, which, as in a case of Bernard's (*Journ. d. phys. esp. de Magendie*, vol. iv.), extend as such for a short distance, and then unite into one common canal.

We must also mention here the so-called branchial cleft fistulæ (*fistula auris congenita*), which, according to the investigations of Schwabach, Kipp, Urbant-schitsch and Katz, have no connection with the development of the external meatus.   They appear as short blind sacs, lined with epithelium, which secrete a milky fluid through a round fistulous opening in the skin in front of or below the tragus, but which do not communicate, however, with the external meatus or with the tympanic cavity.   Sometimes a cystic enlargement of these branchial fistulæ (branchial cyst) takes place.   In a large number of cases they are hereditary.   This anomaly is often bilateral; in the cases observed by the author it occurred more often in the left ear.

Fig. 293.—Auricular Appendage situated in Front of the Tragus in a Boy aged 9 Years.

Fig. 294.—Rudimentary Auricle in the Form of a Long Car-tilaginous Tumour.

Removed.   Healing of the united edges of the wound.   The linear scar which remained was scarcely perceptible.

Anomalies of development of the external meatus are usually combined with defects of the auricle, with partial or complete absence of the middle ear, occasionally with branchial cysts and fistulæ, not infrequently with arrested development of the cranial bones, and, finally, with congenital facial paralysis.   They occur as a congenital stenosis, but more often, however, as an osseous or membranous atresia.   At times all signs of an external auditory canal are absent (Robb, *Amer. Journal of Otol.*, vol. iii.; Hessler, *Stat. Ber. A. f. O.*, vol. xvi.).   In place of the external auditory orifice there is either a shallow depression or a short, blind canal (Welker, *A. f. O.*, vol. i.; Zaufal, *Prag. med. Wochenschr.*, vol. i.; Knapp, *Z. f. O.*, vol. xi.).

In a case of malformation of the right ear dissected by the author he found a rudimentary auricle, the external auditory meatus represented by a fibrous band 1 cm. long, the tympanic cavity absent, and the pharyngeal orifice of the Eustachian tube indicated only by a small fossa.   The osseous and mem-branous labyrinths, however, were perfectly developed, and the terminal filaments of the auditory nerve as well as Corti's organ were in a normal condition.

The following malformations of the tympanic membrane must be men-tioned: congenital absence of the membrane, which always occurs in con-nection with an arrested development of the external auditory canal and of the middle ear; and congenital perforations which have generally been observed in both tympanic membranes at the anterior superior part in the

region of Shrapnell's membrane, and which were associated with cleft palate (v. Tröltsch).

The occurrence of a double membrane is doubtful, and it is probable that in those cases reported by Duverney, Giampietro, and others, it was only a membranous structure which had formed in the external meatus (Schwartze).

Anomalies of formation of the tympanic cavity are: rudimentary development and contraction to the size of the head of a probo (Moos and Steinbrügge, *Z. f. O.*, vol. x.), and complete absence. In addition to these, one finds partial defects of development: contraction (as in one of the specimens in the author's collection) or complete closure of one or both labyrinthine windows, and the absence of the eminentia stapedii and stapedius muscle (Politzer).

The following malformations of the ossicles have been observed: abnormal increase and decrease in size, coalescence of all the bones into one (columellar formation, Toynbee, Politzer), union of both crura of the stapes into one small rod proceeding from the centre of its foot-plate, and, finally, complete absence of one or more of the ossicles.

Abnormalities of the Eustachian tube are usually associated with malformations of the external auditory meatus and of the tympanic cavity, and occasionally also with cleft palate. A congenital dilatation to three or four times its original size has been reported by Cock (*Med. chir. Trans.*, vol. xix., quoted by Schwartze, *loc. cit.*). J. P. Cassels (*Glasg. Med. Journal*, vol. viii.) found, besides a stenosis of the bony auditory canal, a stricture of the osseous portion of the tube. Total absence of the Eustachian tube, with a simultaneous absence of the external meatus and tympanic cavity, has been observed by Moos and Steinbrügge, and in one case by the author.

In addition to partial and complete absence of the external and middle ear, there are, as a rule, also defects of development of the mastoid process, or even with its entire absence. Sometimes the mastoid process is found to be reduced to a short, solid prominence even in those cases in which the remaining portions of the temporal bone are in a perfectly normal state.

The malformations of the internal ear, which occur either with or without co-existing defects in the sound-conducting apparatus, are: complete absence of the labyrinth (Michel, Schwartze), absence of one of, or all, the semicircular canals (Bochdalek, Toynbee, Voltolini, Bremer, and others), rudimentary development of the same (Triquet), absence of the vestibule and cochlea (Montain), or one of the windings of the latter (Hyrtl), absence of the modiolus or lamina spiralis (Nuhn), incomplete development of Corti's organ (Scheibe, Bremer), opening of the fenestra rotunda into the vestibule, dilatation of the aqueducts (Hyrtl), absence of the auditory nerve, but only when there is a simultaneous absence of the labyrinth (Michel), and, finally, absence or faulty development of the striæ acusticæ and of the auditory nucleus. According to Steinbrügge, defects in the ear brought about by an inflammatory process in the early years of life may be mistaken for anomalies due to an arrested development.

The malformations of the internal ear just detailed are, as a rule, associated with total deafness. On the other hand, however, one still finds perception for sound of a varying degree in cases of defective development of the sound-conducting apparatus if the tuning-fork tests show that there is a normal condition of the internal ear. In atresia of the external meatus, speech may still be understood, as the sound waves are conveyed to the labyrinth either by means of the cranial bones or by means of the Eustachian tube.

In cases of unilateral absence of the external and middle ear,

the presence of the labyrinth on the same side can be ascertained by examinations with the tuning-fork. If the tone of the vibrating c^2 tuning-fork placed on the vertex is heard stronger in the malformed ear, it may be assumed that the labyrinth is normally developed; if, however, the tone is lateralized towards the normal ear, it is probable that there is a co-existing defective development of the internal ear on the malformed side.

When there is unilateral absence of the auricle associated with atresia of the external auditory canal, the movements of the soft palate during phonation must always be tested. If there is a symmetrical movement of the palatine arches, it may be assumed with probability that the Eustachian tube and middle ear are in a normal condition. If, however, that half of the palate corresponding to the defective side shows a diminished mobility, one is justified in assuming that there is an impaired development of the tympanic cavity and Eustachian tube, because malformations of the middle ear are often associated with defective development of the muscles of the palate and tube.

Operative interference in congenital atresia of the external meatus is permissible only if one is convinced by a careful examination that one is dealing only with a congenital thin septum at the entrance to the ear, that speech is understood by applying the ear-trumpet to the closed part, and if, during catheterization, the air can be heard to enter the middle ear by auscultation. In cases, however, in which the atresia extends far inwards, and in which the external meatus is not permeable, or feels only like a solid cord, and in cases in which the atresia is bony in structure, and the tuning-fork tests show an absence of sound perception, operative measures would be useless and would, furthermore, be irrational and dangerous

Deaf-Mutism.

Deaf-mutism depends on an anomaly of the organ of hearing. which is either congenital or acquired during the early period of childhood, and which is associated with such a marked diminution in the hearing function that speech cannot be learned by means of the hearing, or where it had already been acquired, becomes lost again.[*]

Heredity and intermarriage between blood relations have been shown to be the most frequent indirect causes of congenital deafness. Hammerschlag has shown, from his statistical investigations, that consanguinity is the etiological factor in deaf-mutism.

Direct transmission is proportionately less often met with than

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[*] Holger Mygrind, *Taubstummheit*, 1894.

the indirect, because marriage between two deaf-mutes is not of frequent occurrence, and is seldom fertile in offspring.

Hammerschlag (*Archiv f. Ohrenheilk.*, vol. lvi.) emphasizes the fact that the customary division of 'congenital' and 'acquired' deaf-mutism does not hold good in reference to the intra-uterine acquired deaf-mutism, and that at least the term 'inherited' deafness be eliminated, and replaced by the more correct term of 'congenital' deafness. He also suggests that deaf-mutism be subdivided into: (1) that caused by local affections of the organ of hearing, and (2) the constitutional deaf-mutism. The first form is always acquired, but can also develop during foetal life. The constitutional form Hammerschlag divides (*a*) into the endemic (cretinoid), and (*b*) into the sporadic forms. Under (*b*) belongs that form of deaf-mutism produced by the consanguinity of the parents, and called by Hammerschlag degenerative deaf-mutism.

In taking the census in the Netherlands, it was shown that among 1,622 individuals deaf-mutism was hereditary in 13·5 per cent. of the cases; of 146 children whose parents were deaf-mutes, five were similarly afflicted (*M.f.O.*, 1896). According to Scheppegrell (*Amer. Med. Journal*, vol. ii., 1900), 13·3 per cent. of the children are deaf-mutes if both parents are likewise affected; 6·8 per cent. if only one parent is deaf. From Fay's (*Marriage of Deafness*, 1898) statistics it was seen that of 5,000 cases collected in America, 8·4 per cent. of the children were deaf when both parents were also deaf. Kreidl and Alexander ascertained the following from 558 deaf-mutes: (1) That deaf-mutism occurred in 3·67 per cent. when the parents were blood-relations. (2) That deaf-mutism was present in 2·3 per cent. of the cases in which the parents were deaf-mutes, hard of hearing, or had affections of the mind. Congenital deaf-mutism was found in 70 per cent., and acquired in 30 per cent. (3) That deaf-mutism occurred in 13·3 per cent. when the marriages were between blood-relations, in whom there was deaf-mutism, hardness of hearing, or mental diseases. (4) The diagnosis of congenital deafness can be made with certainty if there are several deaf and dumb children in one family.

It can more often be shown that deaf-mutism is due to indirect inheritance, especially in those cases in which the ancestors of the patients were also deaf and dumb. The transmission becomes manifest as deafness, affections of the mind, epilepsy, idiocy, stuttering speech, and various forms of nervous diseases. Retinitis pigmentosa has been found quite often as an accompanying affection (Liebreich, Leber, Bezold, and others.)*

Kramer reported the case of a family in which six congenitally deaf and five perfectly normal daughters were born of healthy parents. The author saw four deaf-mutes in a family of ten children, in which no hereditary predisposition could be ascertained. Love found forty-one deaf-mutes among

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* Trombetta and Ostino (*Arch. ital. di Otologia*, etc., vol. x.) made investigations on deaf-mutes to find out what compensation, if any, there was for the loss of function of the acoustic nerve, and found in ten deaf-mutes that: (1) The irritability of the retina was reduced; (2) the monocular field of vision for white and colours was greater, and that the field of fixation was larger than normal. Trombetta and Ostino believe, therefore, that deaf-mutes have a sharper perception for objects moving in the periphery of the field of vision than normal individuals, indicating that the eye compensates for the ear as an organ for the perception of space and direction.

several families which were related with one another. The largest number of deaf-mute children observed in one family was ten.

The statistics vary as to the influence of close intermarriages on congenital deafness. H. Schmaltz (*Ueber Taubstummheit im Königreich Sachsen*, 1884) entirely denies the supposed connection. Bonder is said to have found congenital deafness from intermarriage in 25 per cent., Mitschel in 6 per cent., Hartmann in 8·1 per cent., and Uchermann (*Die Taubstummen in Norwegen*, 1896) in 25 per cent. of 919 cases. Uehermann is of the opinion that, in addition to consanguinity, the hereditary influence which is thereby increased has also a great deal to do with the congenital deafness. Brooks (*Johns Hopkins Hosp. Bull.*, 1900) has shown that deaf individuals, or persons whose hearing is normal and whose relatives are hard of hearing, have a strikingly large percentage of deaf children. If consanguinity of the parents is added to this, 50 per cent. of the offspring may be born deaf.

It is very doubtful whether unfavourable social relations are conducive to the frequent occurrence of congenital deafness; they seem, however, to play a great part in causing acquired deaf-mutism. The frequency of this imperfection is very notice--able among the inhabitants of isolated mountainous regions, and may be attributed to unfavourable social and hygienic conditions, as well as to frequent intermarriages.

Acquired deafness, or deaf-mutism, is caused by primary affections of the ear, by intracranial processes, and by general diseases. The most important of these are: epidemic cerebro-spinal meningitis, the ordinary meningitis, and hydrocephalus; further, the infectious diseases, as scarlet and typhoid fevers, diphtheria, variola, influenza, and tussis convulsiva (whooping-cough), hereditary syphilis, mumps, rickets, and primary affections of the labyrinth, especially inflammations and suppurations of the same (*vide* p. 550), panotitis (*vide* p. 674), and injuries of the internal ear (p. 710).

According to Lemcke (*Die Taubstummheit im Grossherzogthum Mecklen-burg-Schwerin*, etc., Leipzig, 1892; *A. f. O.*, vols. xxxv. and xxxvi.), the various affections of the brain are the cause of acquired deaf-mutism in 38·7 per cent. of the cases; scarlet fever in 24·4 per cent.; to a less degree measles (8·3 per cent.); typhoid fever (3·4 per cent.); diphtheria (1·5 per cent.); whooping-cough (1·5 per cent.); injuries (5·0 per cent.); rickets (about 5 per cent.); and primary affections of the ear (8·6 per cent.).

The numerical proportion between congenital and acquired deaf-mutism varies according to different authors and countries. The statements that the two forms occur equally often cannot be accepted as definitive, as even by a thorough scientific examination in a number of cases it cannot be ascertained with certainty whether the case is one of congenital or acquired deaf-mutism. By a minute investigation of 210 cases of deaf-mutes in Wilh. Meyer's clinic, Holger Mygrind found that the deafness was acquired in 125, and congenital in 54 cases; the etiology of the other 31 cases was undecided (Mygind, *Die angeborene Taubheit*, 1890). That, the data collected in deaf and dumb asylums are often untrustworthy, is seen from the fact that the author has found, in a number of cases which were said to be congenital deaf-mutes, changes in the ear (extensive perforations, adhesions of the membrana tympani, etc.) which showed undoubtedly that the deaf-mutism had been acquired. Schmaltz is also of the same opinion; in 16·2 per cent. of the cases said to have been congenitally deaf and dumb, he found objective changes in the ear, while

in another series of cases, in 39 per cent. of those who were said to have acquired the deafness, no signs of an aural affection could be found. According to Bliss (*Philad. Med. News*, vol. lxvii., 1895) and Frankenberger (*M. f. O.*, 1896), deaf-mutism is acquired in the great majority of cases. The changes are generally localized in the internal ear, but are not infrequently, however, limited to the sound-conducting apparatus.

Birchner (*Der endemische Kropf und seine Beziehungen zur Taubstummheit und zum Kretinismus*, Basel, 1883) believes that we can differentiate a sporadic and an endemic deaf-mutism, the latter of which is always supposed to be associated with endemic goitre. By the action of the virus of this endemic affection, changes in the hearing and speech centres may take place *in utero*, which give rise to deaf-mutism. Endemic deaf-mutism may also be acquired during the first years of life.

The pathology of deaf-mutism is still incomplete, notwithstanding the considerable number of conditions found *post-mortem*. On the whole, however, the information published on this subject gives us a fairly clear picture of the anatomical lesions in the ear, which may be looked upon as the cause of deaf-mutism.

Holger Mygind (*A. f. O.*, vol. xxx.) deserves the credit of having collected 118 cases of deaf-mutism with *post-mortem* findings; these include some of his own cases, and give us instructive information of the changes found in the different parts of the ear. Since this publication the number of cases examined *post-mortem* has increased considerably.*

The following have been shown to be the anatomical causes of congenital deafness: bilateral atresia of the external auditory canals, impaired development or absence of the middle ear, defects and rachitic deformities in the labyrinthine windows (Moos), bilateral osseous closure of the round windows with ankylosis of the stapes and a diminution in the size of the labyrinthine cavity (Politzer), anomalies of formation in the middle ear, with co-existing changes in the ductus cochlearis (Nager), narrowing of the recess of the round window to a cleft with connective-tissue atresia of the same (Politzer), and atrophy of the cochlear nerve and spiral ganglion in the first turn of the cochlea (Scheibe, *Le' r. f. O .renheilk.*, vol. xxvii.); furthermore, abnormalities of the membrane of the otoliths, of the organ of Corti and of the ductus cochlearis (Goerke), epithelium metaplasia with faulty development of the sensory epithelium, combined with ectasia, or collapse of the membranous labyrinthine wall, especially the inferior part (Lindt), defects of the crista and sulcus spiralis, as well as the epithelial cells of the ductus cochlearis, with an abundant formation of hyaline bodies and pigmented patches in the latter (Alt), impaired development of the labyrinth (see p. 731) and of the auditory nerve, inflammatory processes in the middle ear and labyrinth arising *in utero* (Moos,

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Gellé, Politzer), a break in the continuity of the acoustic roots through hæmorrhages (Haike), malformations of the central nervous system, meningitis during fœtal life, and, finally, hydrocephalus (Menière, Castex).

Of the anatomical changes producing acquired deaf-mutism, the following must be mentioned: bilateral acquired atresia of the meatuses, scarlatinal, diphtheritic, purulent, middle-ear suppurations which are associated with exfoliation of the ossicles, and which usually arise during the first years of life, caries and necrosis of the labyrinth, inflammatory changes in the labyrinth, firm adhesions and ankylosis of the ossicular chain, chronic non-suppurative catarrhs with termination in obliteration of the tympanic cavity by the new formation of connective tissue, and, finally, occlusion of the labyrinthine windows through the formation of new bony masses.

The changes found in the labyrinth of deaf-mutes are: inflammatory and retrogressive processes, thickening of the endosteum of the labyrinthine cavity, hyperostotic narrowing of the vestibule and semicircular canals, extensive bone formation in the cochlea with concentric narrowing of the scalæ through otitic bony layers which arise from the endosteum (Alexander, *Monat. f. Ohrenheilk.*, 1906), pathological pigmentation of the internal ear (Panse, *Archiv f. Ohrenheilk.*, 1904 and 1908), thickening of the saccule and utricle, colloid degeneration of the neuro-epithelium in the utricle (Moos and Steinbrügge), new formation of bone in the labyrinthine capsule, and cone-shaped protruding duplications of the endosteum in the scalæ of the cochlea (Politzer), partial or complete obliteration of the labyrinthine cavity owing to the formation of connective tissue and bone (Moos and Steinbrügge, Holger Mygind, Habermann, Burckhardt-Merian, Politzer, Scheibe, Schwabach), defects in Corti's organ, atrophy or hypoplasia of the spiral ganglion and that portion of the cochlear nerve running in the modiolus, and connective tissue and bone formation in the basilar turn of the cochlea with loss of the nerve element after cerebro-spinal meningitis (Schwabach, *Zeitsch. f. Ohrenheilk.*, vol. xli.). Imperfect development of the inferior, left frontal convolution and of the island of Reil has been repeatedly observed (Mygind, Rüdinger); atrophy of the superior convolution of the temporal lobe has been found in only one case (Obersteiner).

Holger Mygind calls special attention to the relative frequency of pathological changes in the labyrinth, especially to total or partial obliteration of the labyrinthine cavity by the deposit of calcareous and connective-tissue masses, and also directs attention to the frequency with which the semicircular canals become involved in the process.

In conclusion, the conditions found in some of the ears of deaf-mutes examined by the author merit description. In a man sixty-one years of age, who was said to have been born deaf and dumb, the external and internal ear were found to be in a normal condition, and the membrane of the round window

very thin and freely movable; in addition to these conditions, chronic internal hydrocephalus and chronic pachymeningitis were found, the striæ acusticæ were slightly developed, and the origin of the left auditory nerve was degenerated into a gelatinous mass.

In a girl eleven years of age, said to have had congenital deafness, the author found the right tympanic membrane cicatrized, the body of the incus (Fig. 295, *b*) embedded in a mass of connective tissue, and the recess of the round window (*a*) filled with connective tissue. On the left side he found an oval perforation 2½ mm. in size in front of the malleus, and the long process of the incus on both sides ⅓ longer than normal, and bent at a right angle (*c*) in its middle portion. The stapes (*d*) was displaced backwards and upwards, and its crura and head were united with the upper wall of the recess of the vestibular window. A condition nearly analogous to the one just described was found at the *post-mortem* examination of another deaf-mute. In this case the long process of the incus and the head of the stapes were adherent to the posterior wall of the tympanic cavity. Owing to a displacement of the entire incus thus produced, the space between the handle of the malleus and long process of the incus appeared widened to a broad, obtuse angle.
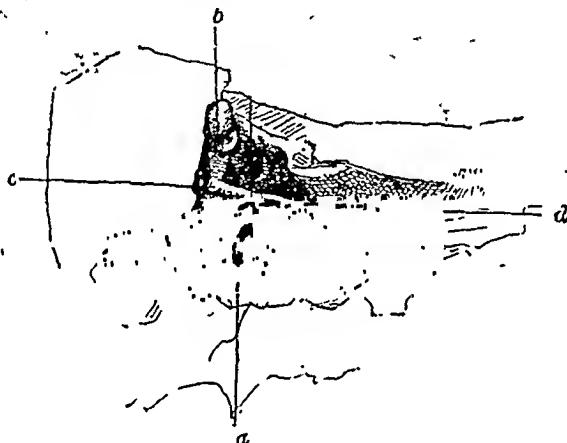
Fig. 295.

In a young deaf-mute who had died in the general almshouse, and whose history and age were not known, the author found at the autopsy, adhesion of the stapes to the posterior wall of the recess, and a slight depression instead of the recess of the round window. Microscopic, frontal sections showed a fissure (Fig. 296, *n*) which ran from the depression to the fenestra rotunda, and which was filled with connective tissue, the meshes of which contained groups of fat cells.

It has not yet been determined whether secondary changes (atrophy from disuse) take place in the sensory cortical centre of the temporal lobe as the result of a congenital or acquired deafness which has existed a long time. Luys reported a case in which he is supposed to have found yellow discoloration and colloid degeneration of the cerebral cortex in addition to similar changes in the acoustic nerve.

The anatomical conditions, however, do not always show whether the deafness is congenital or acquired. It is only in cases of marked impairment of development in the ear, that it can be determined with certainty that the deafness is of a congenital nature. On the other hand, when there is no reliable history, it is often impossible to say whether certain changes, as, for instance, ankylosis of the ossicles, hyperostoses in the windows of the labyrinth, and new growths of connective and bony tissue in the internal ear, date from fœtal life, or whether they developed after birth.

In those cases in which the deafness is acquired during the first years of life, the children do not, as a rule, learn to speak. If, however, the deafness comes on later, let us say between the fourth and seventh years, the power of speech often becomes lost, notwithstanding all possible didactic measures; nevertheless, it is sometimes possible, with intelligent children who have already learned to read, to prevent the development of dumbness by careful attention on the part of those around them. Deafness acquired in the later years of childhood is seldom associated with the loss of speech.

When examining a deaf-mute, it must be ascertained by most careful testing, whether there is total deafness for.every kind of sound. When the perception for sound is entirely absent, the
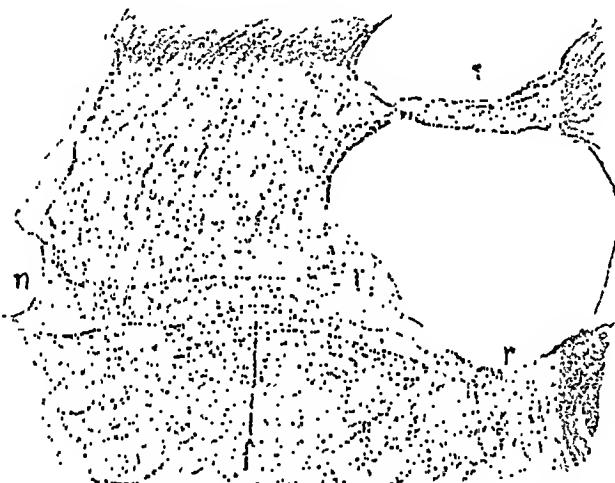
Fig. 296.—Frontal Section through the Niche or Recess of the Fenestra Rotunda of a Deaf-Mute. Age unknown.

r, r', Membrana fenestræ rotundæ; *n*, Slight depression at the base of the niche of the fenestra rotunda; *n, n'*, Narrow osseous fissure, filled with connective tissue containing fat, extending to the membrana fenestræ cochleæ.

deaf and dumb child will not react to sudden noises made behind its back, as, for example, clapping the hands, ringing a bell, whistling, blowing a trumpet, etc.; if, however, some perception for sound is still preserved, the child will reflexly turn its head towards the source of the sound. The perception for sound through the cranial bones must also be tested by placing high and low toned tuning-forks on the vertex and on the mastoid process. When it is found in this test that perception is completely absent, the child will show no reaction, but if the tone of the fork is heard, the child will give evidence of its perception by a change in the facial expression. If it has been proved by the various tests that there is some perception for sound, each ear must be examined separately, to ascertain the hearing power

for vowels and speech. It is thus noticed that some deaf-mutes, and, in fact, more frequently those with congenital than those with acquired deafness, repeat some of the vowels spoken into the ear, especially a, o and u, but less often the consonants (most frequently b, p and r). By long-continued practice the tactile sense of the external region of the ear seems to facilitate the perception for vowels and consonants.*

Hartmann found in 100 cases 60·2 per cent. with total deafness, 24·3 per cent. with perception for sound, 11·2 per cent. with hearing power for vowels, and 4·3 per cent. with hearing power for a few words. According to the statistics of Holger Mygind, it is noticed that total loss of perception for sound is present only in a small number of deaf-mutes, and that total deafness is more prevalent in acquired than in congenital deaf-mutism.

Bezold's examinations (*Das Hörvermögen der Taubstummen*, etc., Wiesbaden, Bergmann, 1896), which were carried out by means of a continuous series of tones on seventy-nine pupils of the Munich Deaf and Dumb Asylum, showed that there is seldom complete deafness on both sides (*fifteen times in seventy-nine cases*); the failure to perceive certain tones within the hearing range was often found as gaps in the scale, and frequently as limited ranges of hearing in the form of tone islands. The hearing power which was still retained embraced two and a half octaves with the exception of two half-tones (islands) in twenty-eight cases; loss of tones from a half to three and a half octaves (gaps) was observed in twenty cases; once the upper portion of the scale could not be perceived while the perception for the lower part was intact; the upper and lower limits of perception were lessened eight times; large defects in the lower part of the scale were present eighteen times; and . light defects in the upper as well as in the lower parts of the scale were observed thirty-three times. The power to perceive the range of tones from b^1 to g^2 was shown to be absolutely necessary in order to understand speech. As a general rule, the failure to perceive tones of the lower scale was more often met with than the failure to perceive those of the upper range, and finally it was noticed that children with some hearing power were found more often among those born deaf and dumb than among those who became so in later life.

The results of Bezold's examinations of deaf-mutes have been confirmed by Passow, Schwendt, Wegener, Barth, Denker, Hasslauer, Kickhefel, Barnick, and others.

The condition of the vestibular apparatus in deaf-mutes was investigated by Bezold, Denker, Hassler, Wanner, Frey, Hammerschlag, Nager, and Brock. Brock (*Archiv f. Ohrenheilk.*, vol. lxxi.) found that in those persons who were totally deaf no irritability of the vestibular apparatus could be elicited when testing with the caloric method of Bárány. Bárány observed, in persons who were totally deaf, a slighter rolling of the eyes in the opposite direction, than in persons with a normal hearing (*Archiv f. Ohrenheilk.*, vol. lxviii.).

Kreidl (*Pflüger's Archiv*, vol. li.) examined 109 deaf-mutes, and found that in nearly 50 per cent. the jolting movements of the eyes which generally appear in a normal person when rotated on a vertical axis were absent. He there-

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* We are indebted to Uchermann for valuable information in reference to the examination of deaf-mutes (Intern. Med. Congress, London, 1897).

fore concluded that in about 50 per cent. of deaf-mutes the semicircular canals are affected, and that they cause these movements of the eyes and dizziness. Of sixty-two deaf-mutes placed on a roundabout, thirteen had no difficulty in retaining the vertical position, while of seventy-one individuals with normal ears, all were able to retain this position with the exception of one. The deficiency of this sense is associated with the failure of the eyes to roll in the opposite direction, according to Alexander and Bárány. Alexander and Kreidl (*Arch. f. d. ges. Phys.*, vol. lxxxix.) found that in persons who were born deaf-mutes the galvanic reaction was absent in 31·2 per cent., while in persons who became deaf after birth, in 71·1 per cent. From the investigations carried on by Alexander and Kreidl it was found that with marked anatomical changes in the vestibular apparatus the galvanic reaction is absent, but with slight changes it is normal. Hammerschlag (*Zeitsch. f. Ohrenheilk.*, vol. xlv.) found that in twenty-three hereditary deaf and dumb children, twenty-two (95·6 per cent.) showed a positive reaction to the galvanic current when passed through the head, by an unsteadiness of the head and body.

The proposal of Passow* that in the beginning of each school-year in the deaf and dumb asylums the newly-admitted pupils should undergo a thorough aural examination deserves consideration, as changes are often found in the ears which are the cause for the defective hearing. Such children are often no fit subjects for an asylum, as a timely treatment of their nasal and aural condition frequently improves their hearing to such a degree that they readily learn to speak, and no longer come under the category of deaf-mutes. The author has repeatedly found that a high degree of deafness was due to a chronic middle-ear catarrh in children who were to be admitted into a deaf and dumb institute; by proper local treatment the affection improved to such an extent that their admission became unnecessary. The promiscuous admission of children into an asylum, among whom some are almost deaf, some affected with catarrhs, others neglected in their training, others again hard of hearing on account of idiocy, explains why in some pupils (about 6 per cent.) during their confinement in the institution a spontaneous improvement in the hearing takes place, which, when the hearing tests are undertaken, is erroneously regarded as the result of their training at the institution.

Prognosis.—According to the experience of the author, the prognosis of deaf-mutism is, on the whole, unfavourable, yet it is more favourable in the congenital than in the acquired forms. In a number of children in whom the author diagnosed congenital total deafness, he was able to note several years later that speech could be heard at a distance of $\frac{1}{2}$–$1\frac{1}{3}$ m. and over. In the majority of cases this improvement in hearing was observed only in one ear, while the other remained deaf.

On the other hand, the author has never observed an improvement in the hearing in a single case of total deafness due to a scarlatinal or diphtheritic middle-ear process, or after meningitis and hydrocephalus, in spite of the fact that aural examinations were repeatedly undertaken.

Treatment.—Treatment is of benefit only in those cases of deaf-mutism in which there are pronounced objective symptoms of a middle-ear affection. In those cases in which there is a high degree of deafness in consequence of a congenital or infantile middle-ear catarrh (which had been overlooked), so that the acquisition of speech is thus rendered impossible, favourable

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* *Verh. der deutsch. otol. Gesellschaft*, 1889

results are not infrequently obtained by a methodic application of inflations of air. It is always advisable, therefore, in deaf children who have a greatly retracted tympanic membrane, or who have symptoms of mucous secretion in the middle ear, to try inflations of air, and to continue them for several weeks in order to see whether one cannot bring about an improvement in the hearing. Jacquemart (*A. f. O.*, vol. xxi.) brought about recovery in a deaf and dumb child, in whom both tympanic membranes were cloudy and retracted, by inflations of air into the middle ear through the catheter, which had been continued for some time. Krebs, Love, Urban Pritchard, Cassiani, and others have reported marked improvement in the hearing in deaf-mutes by the relief of a chronic naso-pharyngeal catarrh, and by the removal of adenoid vegetations from the naso-pharynx. All treatment remains ineffectual in total deafness caused by scarlatinal and diphtheritic ulcerative processes in the middle ear and labyrinth, by panotitis, and by intracranial diseases.

Systematic instruction of the deaf and dumb, which is usually begun in the first years (fourth to fifth year), is of great importance from an educational standpoint. Gutzmann and Flatau recommend sending deaf and dumb children to kindergarten before these ages, in order to prepare them for future instructions in articulation and power of observation. The instruction, which is now highly developed and systematically carried out in well-organized institutions for the deaf and dumb, renders the pupils capable, just like normal individuals, of expressing their thoughts by speech and writing, and of acquiring a certain amount of mental culture. This is accomplished rather easily by careful training, as the majority of deaf and dumb individuals are well endowed mentally.

A Spanish priest, Pedro Ponce, who lived in the second half of the sixteenth century, is said to have been the founder of deaf and dumb instructions. In the eighteenth century the Abbé de l'Epée, who introduced the language of gesture, and Heinicke of Leipzig, who introduced the phonetic system (German method),* founded deaf and dumb institutions. The phonetic system, which has been principally developed in Germany and Austria, has also been adopted by other countries, while the method of signs and gestures is now used only to a limited extent. The congresses for deaf-mutism which have taken place within the last decade have decided that the phonetic system is the only correct method of instructing the majority of deaf-mutes.

The speech acquired by deaf-mutes by proper instruction is sometimes so clearly articulated that it is understood without the least difficulty. In others, however, the speech is indistinct, and it is possible only by the greatest attention and by repeated intercourse to comprehend what the individual is trying to express. Even in those persons whose speech is easily understood there is a peculiar unpleasant harshness, because the deaf-mute possesses no guide by which he is able to modulate the pitch of his voice. This explains why speech usually sounds rough and indistinct in persons who are afflicted with complete deafness, and, on the other hand, more in-

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* Cp. Politzer, *Geschichte der Ohrenheilk.*, vol. i., p 427.

telligible and less unnatural in those who possess a slight degree of perception for sound, for vowels, or even for speech.

In addition to the phonetic system of improving the speech, Hamon du Fougeray also proposes instruction by singing in those pupils who still show a sufficient power of perception for musical tones.

The so-called *Hörstummheit,** idiotic dumbness and psychical deafness, must not be mistaken for deaf-mutism. Cases of loss of speech not accompanied by hardness of hearing were already known to the older otologists. Wilde† is said to have found a large number of such cases among the deaf-mutes of Ireland. Several similar observations have recently been reported by Kussmaul,‡ Broadbent, Uehermann, Benedikt, Treitel, Waldenburg, Gutzmann, Liebmann, and others. R. Coen,§ who observed a large number of cases, considers *Hörstummheit* of a congenital nature. Hammerschlag (*Zeitsch. f. Ohrenheilk.*, vol. xlv.) believes that *Hörstummheit* may also be an acquired disease. Hereditary predisposition is regarded as the cause of congenital *Hörstummheit*, while traumatic and psychical conditions seem to be important factors in the production of the acquired form. According to Hammerschlag, it develops in children after an infectious disease (measles, scarlet fever, typhoid fever, etc.), and may be traced to encephalitic processes.

From the large number of cases reported in literature it is found that *Hörstummheit* does not occur very often. This may be explained by the fact that in the majority of cases there is either no otoscopic condition recorded, or a thorough examination of the hearing has not been made, and, further, that slight forms of idiocy have not been excluded. The diagnosis of *Hörstummheit* is made from the history of the case, and from the excitable disposition, anxious look, sudden anger, occasional mental depression, etc., of the patient. From the material which is now at hand, it seems that the true form of *Hörstummheit*‖ is of rare occurrence, and that it is difficult to separate it from idiotic dumbness (Alt, Treitel).¶

Idiotic dumbness is observed in varying degrees. In the slighter forms there is only an impaired development of speech, while in the second stage—namely, imbecility—the speech is developed, but the vocabulary is limited and reduced to only the simplest phrases used in daily life. In the most advanced forms, which Kraus and Kussmaul regard as the most severe stage of idiocy, speech is wanting entirely, or it is limited to a stammering of articulated sounds. There is no doubt that in the latter form marked changes in the speech centre give rise to the dumbness. In the slight forms of idiocy, however, the lack of comprehension for speech depends on the degree of deafness, and on a more or less feeble condition of the mind.

Heller, of Vienna, considers psychical deafness as an abnormal psychical condition of childhood, which, having the symptoms of deaf-mutism, is often mistaken for it, and which is essentially a disturbance of the comprehension for speech which has reached such a stage that it has become almost entirely lost. Children, the subjects of psychical deafness, not being able to comprehend the words which they repeatedly hear, are therefore the more unable to bring about an association of ideas. There are periods in which such children do not react to any form of sound which they in reality hear, and present the appearance of deaf-mutes. This condition is made worse if there is a co-existing deafness. The case may be considered one of psychical

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* By this term, which has lately been introduced into German medical literature, a condition is meant in which the child appears to be deaf and dumb, but in reality possesses the power of hearing.

† *Practical Observations on Aural Surgery* (German translation by Haselberg, 1855).

‡ *Störungen der Sprache*, 1885.

§ *Die Hörstummheit* (Wien. Klinik, 1888).

‖ Liebmann, *Ein Fall von reiner Sprachtaubheit*, 1898.

¶ *Ueber Hörstummheit* (Z. f. O., vol. xxxvi.).

deafness if the person affected uses fragments of words; the diagnosis is substantiated by the fact that children having this form of deafness may attain their full power of speech by means of their hearing, which is never the case with true deaf-mutes. In a number of cases, Heller showed that he obtained splendid results by means of pedagogic training methods.

According to Alt,* the three conditions, *Hörstummheit*, idiotic dumbness, and psychical deafness, are not different processes of disease, but all belong to the same category, and only represent a complicated nomenclature expressing the degree of weakness of mind and the degree of deafness. Whether, according to the opinions of different authors, this is the correct view, remains to be seen.

A form of apparent deaf-mutism may be attributed to a check of mental development. Individuals who have become hard of hearing during their early childhood, and who are not in a position to learn speech on account of their surroundings, as, for instance, those living on a lonely farm, are sometimes regarded as deaf and dumb; if, in such cases, no endeavour has been made in their early youth to develop their power of forming word-pictures, they grow up apparently as deaf-mutes.

An analogous impairment of development may give rise to an apparent deafness in children of deaf and dumb parents, as was observed in a case by Alt (*Monat. f. Ohrenheilk.*, 1899).

The forms of disturbances of speech in children as recorded above are of interest to the otologist, because, up to the present time, the majority of children with such disorders have, without a thorough examination, been placed in deaf and dumb asylums, where the true nature of the affection was discovered only after some years. Bezold† found among seventy-nine pupils of the Munich Deaf and Dumb Asylum, nine children who learned to talk because they possessed sufficient hearing power. Schwendt and Wagner‡ report six similar cases among forty pupils. If specialists, after a careful aural examination of all applicants, would state whether a pupil should be admitted into a deaf and dumb institution, such forms of disturbances of hearing as mentioned above would be discharged as unsuitable for admission.

The endeavour to improve the hearing in deaf-mutes by exercises in hearing is not a new idea. As far back as at the beginning of the nineteenth century (1805) Itard tried to bring about an improvement in the hearing in deaf-mutes by systematic exercises in hearing, which, however, did not meet with much success. In like manner the tests with exercises in hearing which were carried out in 1825 by Blanchet, and in 1835 by Dr. Baries in the Deaf and Dumb Asylum of Berlin, remained fruitless. Since that time we find in the otological works of Lincke, Wolf, Toynbee, and others references to exercises in hearing in deaf-mutes, which, however, were not considered of much value.

At the end of the 'eighties' of the last century, Abbé Verrier, of Bourg la Reine, published quite a number of exaggerated accounts obtained with hearing exercises in deaf-mutes by means of a hearing-trumpet; these exercises, however, were pronounced useless in France and Germany, and the author was able to convince himself of their fruitlessness in a number of cases treated by this method.

In 1893 v. Urbantschitsch§ also commended the value of these hearing exercises in cases of total deafness. He based his theory upon the fact that the loss of the hearing power in deaf-mutes is due to a morbid condition of the auditory nerve, owing to inactivity, which may be aroused and stimulated by exercises in hearing. Most authorities do not agree with Urbantschitsch, for it has been shown that, in the great majority of cases of deaf-mutes there is not only an inactivity of the auditory nerve, but an impaired development of the hearing apparatus, or marked changes in the labyrinth (new formation of

* *M. f. O.*, 1899; *Oest. otolog. Ges.*, November 28, 1899.
† *Das Hörvermögen der Taubstummen*, Wiesbaden, 1896.
‡ *Untersuchungen von Taubstummen*, Basel, 1899.
§ *Wien. klin. Wochenschr.*, 1893.

bone, ankyloses of the stapes, and degeneration of Corti's organ and of the auditory nerve), which exclude all possibility of stimulating the power of hearing. It is not possible by exercising the hearing to restore the function of a diseased atrophic nerve; and even in cases in which the labyrinth and auditory nerve do not show any or slight changes, the disorganized central nuclei of the nerve cannot be aroused by hearing exercises.

Treitel* obtained no satisfactory results with hearing exercises, even in those pupils who could still perceive vowels and repeat short sentences without any previous practice. An ordinary conversation was out of the question, even with the best scholars. In the majority of cases the improvement which had been acquired with great effort again became lost. According to Treitel, it is also seen that, in those cases in which good results are obtained by training, there are a number of children who must be considered *Hörstumm*, or psychically deaf, and who should therefore not be regarded as deaf-mutes.

Similar negative results as to the value of hearing exercises in deaf-mutes were obtained by most otologists who thoroughly investigated the subject of deaf-mutism. According to Bezold,† it is absolutely impossible to bring about an increase in the hearing power by hearing exercises. He never was able to observe an increase in the hearing distance, or a strengthened perception for sounds which were not previously heard, after hearing exercises with tones. The experience of every practitioner shows the impossibility of stimulating the auditory nerve apparatus by simple acoustic exercises; for, if we take into consideration the destructive processes in the labyrinth, which have; as a rule, run their course, and which are met with in deaf and dumb pupils, it becomes self-evident that these hearing exercises cannot be of any benefit. Passow‡ found, in deaf-mutes, that the limit of perception for tones had not been increased the least by hearing exercises. Kessel (*ibid.*) does not consider it possible that a person deaf to tones can ever be made to understand speech. Uehermann§ also considers the possibility of improving the hearing in deaf-mutes by hearing exercises out of the question. The opinions of Heimann (*ibid.*), Schwendt, and H. Gutzmann‖ agree with those of Uehermann. Gutzmann believes that a permanent marked improvement in the hearing, or one of practical value, cannot be obtained in deaf-mutes by exercises in hearing. The author himself was not able, in the deaf-mutes treated with the hearing exercises, to obtain any degree of comprehension for speech in a single case.

The directors and teachers of the most prominent deaf and dumb institutions of Germany have been opposed to the introduction of these exercises in hearing.¶

Bezold** expresses the opinion, based on examinations which he carried out in the Deaf and Dumb Asylum of Munich, that only in those deaf-mutes in whom there is a perception for vowels and words should these exercises be used for instruction in speech. His examinations with a continuous series of tones showed that a hearing power for speech was present only in those deaf-mutes in whom it could be demonstrated that the perception for a considerable portion of the tones (b^1 to g^2) was at hand. According to Bezold, therefore, the test with a continuous series of tones is the only positive means

* *Ueber das Wesen und den Werth der Hörübungen bei Taubstummen und hochgradig Schwerhörigen (Haug's klin. Vorträge*, Book II., vol. xi.).

† *Verhandl. der deutsch. otolog. Ges. in Würzburg*, 1898, and *Archiv f. Ohrenheilk.*, vol. xlvii.

‡ *Ver. der deutsch. otolog. Ges. in Würzburg*, Jena, 1898.

§ *Comptes rendus du XII. Congrès internat. de Médecine à Moscou*, 1897 (W. Roth).

‖ *Handb. der Krankenversorgung und Krankenpflege*, vol. i., part ii.

¶ G. Ferreri, *La facoltà auditiva nei sordomuti*, Firenze, 1899.

** *Z. f. O.*, 1897; and *A. f. O.*, vol. xlvii.

by which it can be determined whether there is still some power of hearing left. This method of testing may be considered, therefore, as the only positive means by which it is possible to examine the deaf-mutes which are to be instructed by ear. In accordance with this, the institutions of Munich and those of other places put those pupils in whom the tests with a continuous range of tones show a power of perception for the tones from b^1 to g^2 into a special class, which is known as the 'Class of Speech Instruction.' Director Koller (*A. f. O.*, vol. xlvii., p. 196) emphasizes the fact that the power of hearing is not improved in the least by this method of instruction, but that the aim of all these instructions in speaking is to teach the pupils how to associate organically the words of ordinary conversation which they perceive by imitating the motions of the lips with those which they have perceived by means of the ear. The instructions in speaking are given, according to Koller, to those pupils who prove themselves apt, in such a manner that the children are kept first for one year at the customary exercises (instructions in articulation) for the deaf and dumb, and are then given instructions in speaking. The greatest attention must be paid to reading the lips. The main object is not to improve the hearing, but to bring about the power of combining thoughts; this is accomplished by the intelligence of the individual, and by the instructions in articulation, inasmuch as whole sentences can be put together from the order of perception of the vowels and from small fragments of words. The author fully agrees with the views expressed by Koller (*Wien. med. Blätter*, 1899, No. 10).

The method described above, which was perfected by Bezold and Koller in Munich, was accepted as the basis for instructing the deaf and dumb by the majority of directors and teachers of deaf and dumb institutions of Germany.

Exercises in hearing for deaf adults were recommended by Philippe as early as 1846 in a treatise, *Über Geistes- und Gehörgymnastik, als unerlässliche Ergänzung der Kur der Taubheit*,* but were not regarded by anyone as of practical value. In 1893 they were recommended by Maloney, of Washington,† who used a hearing-trumpet especially constructed for this purpose. This American otologist showed that these exercises were entirely useless. According to Philippe and Urbantschitsch,‡ the important question of methodical hearing exercises in adults consists in arousing the organ of hearing from a state of dulness and dormant condition, of concentrating the attention upon the sensations of sound, and of keeping this constantly in a state of activity, so that it is advisable to allow these patients to attend theatres, concerts, etc.

The idea that a permanent improvement in the hearing may be brought about by concentrating the attention upon certain noises and tones must be regarded as illusory, inasmuch as the concentration of the mind is in itself a true psychical act. But it has also been practically demonstrated that long-continued strained attention is injurious to the deaf individual, as giddiness, increased subjective noises, and a diminution in the hearing are often observed after a conversation of some duration.

In the chronic disturbances of hearing, where we have to do with adhesive processes in the middle ear and otosclerosis, the value of these hearing exercises must from the very beginning be regarded as illusory. If it is assumed, however, that the auditory nerve can be slightly aroused by electric irritation or by reflex impulses from the trigeminus nerve, it must, on the other hand, be unquestionably acknowledged that this slight improvement in the hearing is always only of a short duration, and for that reason the amount of increased

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* *Journal de Médecine de Bordeaux*, 1846, and Froriep's *Notizen*, vol. iii. Cp. Politzer. *Geschichte der Ohrenheilkunde*, vol. i., p. 449.

† *Otacoustic Treatment. its History and Results upon the Deaf and Deaf-Mutes*, Washington, 1893.

‡ *Versammlung deutsch. Naturforscher und Aerzte in Wien*, 1894.

hearing power gained by means of these hearing exercises is only of a temporary nature. In not a single case in which the hearing exercises were carried out for a considerable time could the author observe a true improvement in the hearing. It is the reading of the lips combined with the slight perception of sound that is of value to the patient; this, however, depends on the intelligence of the individual, and on his daily intercourse with those about him, so that it does not require any special teaching.

Reading the lips is far more important for the social intercourse of persons having a marked degree of deafness. Children who have become totally deaf or hard of hearing, rapidly and easily acquire a most remarkable skill in this way; this is, however, not the case in adults. In the latter, learning to read speech from the movements of the lips depends partly on the ability and power of comprehension of the individual, and partly on the hearing power which he still possesses. The importance of special instruction in this method, which has been especially recommended by Lucae, Treitel, Benedikt, Gutzmann, and others, is shown by the fact that in Berlin and in other cities teachers devote themselves entirely to this subject, and that the results obtained in the courses attended by a great many are very satisfactory. In the author's opinion, instructions in reading the lips might also be recommended to such persons whose deafness has not yet reached a high degree, and also to those—patients in whom an otosclerosis is running a progressive course—in whom the development of a marked hardness of hearing can be predicted with great probability.

Instruments to Aid the Hearing Power of the Deaf.

The instruments which are used in a great many forms of severe deafness serve the purpose of collecting the waves of sound, and of conducting them in a concentrated form to the ear, thereby facilitating social intercourse.

All the various forms of apparatus are so constructed that the waves of sound are collected, and conducted to the tympanic membrane or directly to the internal ear.

Dr. L. Kugel found by thorough tests of hearing, that the tick of a watch and whispered speech are heard much better, if the sound is directed towards the ear (direct hearing) than if the face is turned towards the source of the sound; he also found that the tick of a watch is perceived at thrice the distance if the surface of the auricle is enlarged by placing the palm of the hand behind it.*

In order to ascertain the degree of hardness of hearing, and to determine whether the auditory nerve has completely lost its function or is still capable of sound perception, several ingenious appliances have been devised under the name of the audiometer. This contrivance does not only serve the purpose of apprising us of the total or partial loss of the auditory function, but it also affords us a means of telling accurately the degree of improvement in the hearing obtained during the course of treatment of the aural affection. The ideal hearing tests obtained by means of an audiometer affords an accurate quantitive measurement of the acuteness of hearing for all tones. The wide range of the normal hearing which comprises the uppermost tones of the scale to the lowest tones with the minimum vibrations can be definitely measured,

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* Cp. Galen, *Opera omnia. De usu partium*, vol. xi., chapter xii.; and Politzer, *Geschichte der Ohrenheilk.*, vol. i., pp. 28 and 426.

so that the limitation of the hearing range in a deaf individual can be definitely determined by accurate measurements and compared to the normal hearing ear. There are a number of these audiometers in use, amongst which may be mentioned the pitch range audiometer of Bunch,[*] the instrument devised by Hayes,[†] and of more recent date the electrical audiometer developed by the Bell Telephone Laboratories.[‡]

All these appliances have as their object a means of measuring accurately, the acuity and quality of the sound perception. Being of mechanical construction, they produce a sustained even pure tone, and at the same time make it possible to adjust the pitch and intensity of the sound. In this way we always get a tone of even intensity and duration, and are thus able to measure the improvement in the hearing, if any, with a degree of certainty.

The endeavour to improve these instruments has led to the construction of a great number of appliances which vary greatly in form and size. It is unnecessary to go into a detailed description of the most strange forms of these worthless apparatus, which are depicted in the older works of Lincke, Wolf, Lambert, and others. The trumpet-shaped hearing-tube, with its wide orifice directed forwards, and the parabolic, bell-shaped hearing-cup, are the two instruments which were most commonly used. These consist of a metal beaker, curved in the form of a parabola, from the focus of which the sound-waves are reflected into a second sound-collector, which is pushed into the beaker and is attached to the ear-piece (Fig. 297.) Owing to the size and cumbersome construction of these instruments, they are no longer used as patients prefer appliances which are less conspicuous.

An instrument to aid the hearing of a deaf individual is indicated when the disturbance of hearing is so marked that the patient is no longer in a position, with the simultaneous aid of reading the lips, of understanding speech at a very close range. In this case the hearing-

FIG. 297.

trumpet gives relief to the patient, inasmuch as the long-continued strained attention without the aid of such an instrument gives rise to a feeling of fatigue and tightness in the head. In order to hear speech at a greater distance, a suitable hearing-trumpet or audiphone must be adopted. Individuals hard of hearing, who can still hear ordinary speech at a distance over $1\frac{1}{2}$ m., are advised not to use a hearing-trumpet for close conversation if possible, inasmuch as they become accustomed to such an appliance, and are finally unable to get along without one. The statement that the hearing becomes impaired by the use of a hearing-trumpet is erroneous. An apparatus to aid the hearing is contra-indicated if headache or increased tinnitus arise after it has been used for some time. This unfavourable action
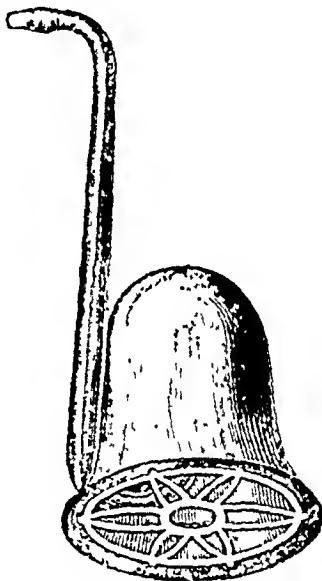
[*] C. C. Bunch, *Laryngoscope*, No. 31, p. 760.
[†] Harold Hayes, *Laryngoscope*, 1913.
[‡] The audiometer, Western Electric Company, New York City.

often depends on the form of the instrument, and on the material from which it is made; it is therefore advisable to allow the patient to try different forms of hearing instruments, and to ascertain in each case which is the most suitable.

For ordinary conversation the most serviceable instrument is a tube $\frac{2}{3}$–1 m. long, made of a closely-compressed spiral wire, the outer surface of which is covered with a layer of leather, which in turn is enveloped in a cover of closely-spun yarn (Fig. 298).

The olive-shaped ear-piece which is inserted into the external meatus of the patient is either straight or bent at an angle. The mouth-piece has the form of a beaker. or, more practical still, that of an ordinary funnel. Hearing-tubes having a conical form —that is, decreasing from the mouth-piece towards the ear-piece —are decidedly more effective, and are to be preferred to those having an uniform calibre in their entire extent. In using the hearing-trumpet, the funnel-shaped extremity is brought close
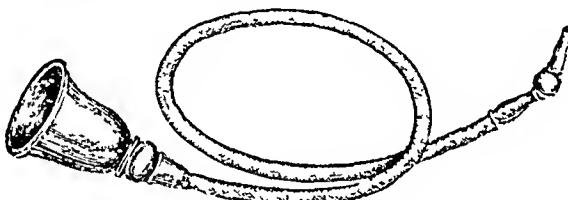
FIG. 298.

to the mouth of the speaker, and it is usually quite sufficient to speak in the ordinary voice in order to be understood by the patient. Speaking too loudly into the hearing-trumpet is not well borne by the patient, owing to a hyperæsthesia acustica which generally exists, and on account of the feeling of tightness in the head which sometimes arises.

Numerous apparatus of varying designs have been constructed to improve the hearing. In addition to the simple conical hearing-trumpet mentioned above, Leiter's and Kugel's instruments have proved most serviceable for this purpose.

During the last few years small instruments to aid the hearing have been constructed which are connected to the upper end of a cane, to a fan, or to an umbrella, in order to render their use less noticeable.

L. Kugel[*] has constructed a hearing-trumpet which has proved serviceable in practice, and which has the advantage of eliminating the annoying secondary noises met with in other instruments. This instrument is constructed on the principle of the groove-shaped auricles of animals (ass, horse, etc.), which, by their formation, act as sound-receivers. The hearing-trumpet of Kugel

* *Wien. med. Wochenschr.*, 1898 and 1899.

consists (Fig. 299) of an open groove with a sound-receiver attached to it. The instrument is perforated by a large number of holes, whereby the secondary noises are overcome.

The so-called 'otophones' have proved of little value, and have been more or less discarded. Recently, a microtelephone and other electrical hearing devices have been constructed to facilitate social intercourse of persons hard of hearing. These devices, which are manufactured in large numbers and of varied designs, are all made on the same fundamental principle—namely, to collect the sound-waves and to convey them to the middle ear, through which they are transmitted to the terminal filaments of the auditory nerve in the labyrinth. The majority of instruments which were formally much in vogue are now being discarded, and replaced by apparatus less conspicuous and constructed on a telephonic principle. There are quite a number on the market, as, for instance, the audiphone, otophone, auri-
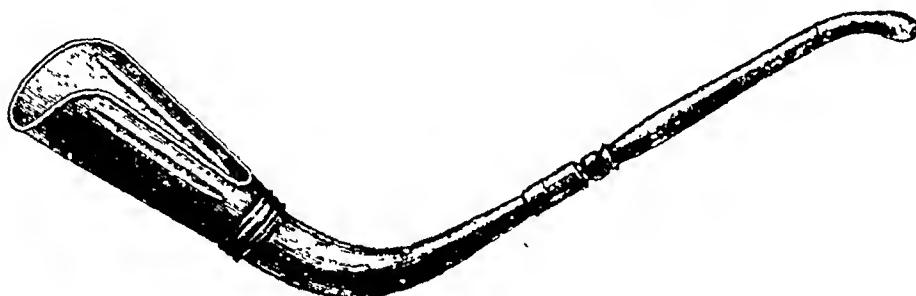
FIG. 299.

phone, the De Forrest, and a number of others, each having its good points and of great value in a large number of cases. There is no instrument that can be termed the best, as one may give satisfactory results in one case and prove very unsatisfactory in another. The deaf individual must try several, and select that one giving the best results.

All of these electrical devices consist of a microphone which is connected with a number of small dry cells, and carried by the patient in such a place that the sound-waves strike the disc directly. By means of a wire, these waves are transmitted to the ear-piece or telephone receiver, and thus conveyed to the middle ear. A movable device on the back of the ear-piece allows one to regulate the intensity of the sound. One factor which is particularly troublesome to most patients is the production of overtones or noises; these interfere with the sound perception, and often cause headaches, a fullness in the head, and a certain degree of tinnitus, so that the individual cannot use such a device, in spite of the fact that it improves his hearing.

In addition to these electrically constructed appliances, other instruments have been devised, based on the principle of bone

conduction. One of these, known as the audiphone of Rhodes (Fig. 802), is made of a flexible hard rubber plate or a varnished piece of cardboard. The lower part is connected with a handle, while the upper part is covered with a small metallic plate which is placed against the teeth or cranial bones. When the sound-waves strike the rubber plate, they are conveyed by bone conduction to the labyrinth. It goes without saying that this appliance is of no value in those cases in which the impairment in the hearing is due to an affection of the labyrinth or auditory nerve. We do not possess as yet any communications in reference to experiments carried out by the wireless telephone or radio on persons hard of hearing.

On account of the great variety of instruments to aid the hearing, and their markedly different effect even in the same individual, it is advisable, in those cases in which the use of one of these instruments is indicated, to try a number of them. It has already been mentioned that some patients with a high degree of deafness hear better without a hearing-trumpet—that is, by conduction of the waves of sound through the cranial bones.

The number of deaf persons is very small who do not object to the ungainly and conspicuous appearance of inconvenient and noticeably large hearing-trumpets. In spite of the advantage gained by the use of larger instruments, they are usually discarded.

The ideal of persons hard of hearing has always been a small instrument which could be worn unnoticed in the ear, and which would prove as beneficial as the large hearing-trumpets.

The small hearing-trumpets which have been put on the market under many different names, of which Abraham's, consisting of a short silver tube with a funnel-shaped nozzle, is the best known, have all proved utterly worthless.* The variously constructed spiral and coiled tubes have proved just as valueless. In all these instruments a physical or physiological principle is lacking, upon which the concentration, or increased strength, of the sound could be based.

From a number of experiments in physiological acoustics which the author carried out, he devised a small instrument which brought about a considerable improvement in the hearing in a number of deaf individuals.

The principle upon which it is constructed is based upon the fact that a sound-wave striking the ear is heard louder if the surface of the tragus is enlarged backwards.

The instrument constructed by the author serves the purpose of enlarging the surface of the tragus backwards, in order to lessen as much as possible the loss of the sound-waves as they are reflected outwards from the concha—that is, to conduct a greater number of waves of sound to the external meatus.

* Cp. Schwabach's article *Hörröhren* in Eulenburg's *Real-Encyklopädie der medicin. Wissenschaften.*

The small instrument (Fig. 300) has a form almost similar to that of a hunting-horn, tho narrower, inner end of which (*a*) is inserted into the external meatus, while the outer, broader part rests in the auricle in such a manner that its orifice (*b*) is directed backwards towards the concha. The size of this instrument varies according to the width of the external meatus and size of tho auricle—that is, the concha. There are three different sizes, which are sufficient for all cases. The larger instruments are 2½ cm. in length; the diameter at the larger orifice is 18 mm., at the smaller end 5 mm.

Fig. 300.—Actual Size.

The smaller ones are about 2 mm., the smallest 3 mm. less in size, and are made of hard rubber. The smaller segment of the tube is cut out on its concave side to the extent of about ⅓ of its circumference. The instrument is introduced into tho external canal by directing the broader orifice upwards, and pushing the narrower end into the external meatus, whereupon tho instrument is rotated in such a manner that the larger orifice points backwards towards the concha.

The improvement in the hearing brought about by the use of this small instrument is, on the average, double that of the previous hearing distance. In more than half of tho cases this instrument had no influence on the hearing distance.

In some cases of deafness tho author uses an instrument to improve the hearing which he devised, and which is based on the principle that the vibrations of the cartilage of the auricle
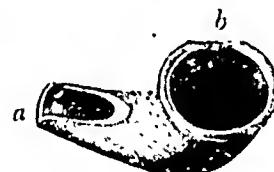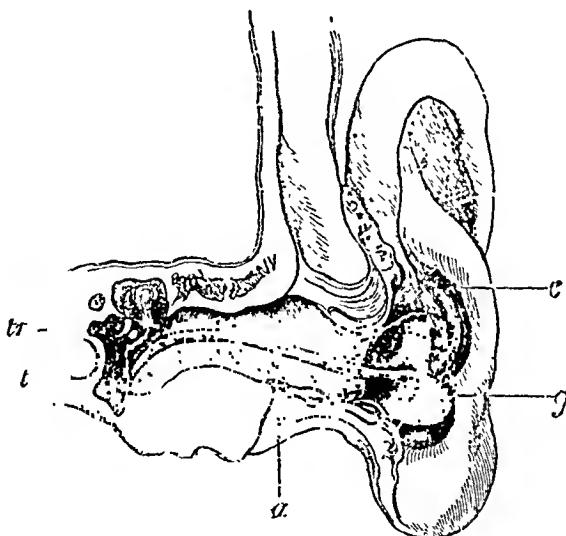
Fig. 301.

are transmitted to the tympanic membrane by means of an elastic sound-conductor.

It consists of a small rubber tube (drainage-tube) 4–5 cm. in length and 2 mm. in thickness, the inner end of which is cut off as shown (Fig. 301, *a*). This extremity is brought into contact with the tympanic membrane (*t*), while the outer curved extremity

(c) lies against the cartilage of the auricle. The action of this instrument is further increased by a round rubber plate (g), which is fastened near the outer extremity of the sound-conductor. The improvement in hearing produced by the use of this instrument is occasionally four to five times the previous hearing distance. It proves most beneficial in middle-ear catarrhs in which the tympanic membrane is relaxed, but is utterly worthless in cases of rigidity and ankylosis of the ossicles.

The results which have been obtained with these audiophones have by no means fulfilled all that was expected of them. Repeated trials by Knapp, Lennox Browne, Joly (Lyon), and
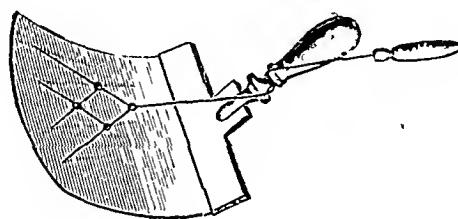
Fig. 302.

others, have shown that the audiophone produces an improvement in the hearing in only a few deaf individuals, and that its beneficial effect is much inferior to that obtained by means of the hearing-trumpet or any of the other mechanical devices.

The author can confirm these statements from his own experience. Audiophones prove most effective in hardness of hearing following a middle-ear suppuration which has run its course, but are of little value in otosclerosis. The author has, however, repeatedly noticed a striking improvement in the hearing in the latter affection by the use of the hearing-plate (Burckhardt-Merian). In affections of the auditory nerve the improvement in hearing by means of any hearing device is generally very slight.

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